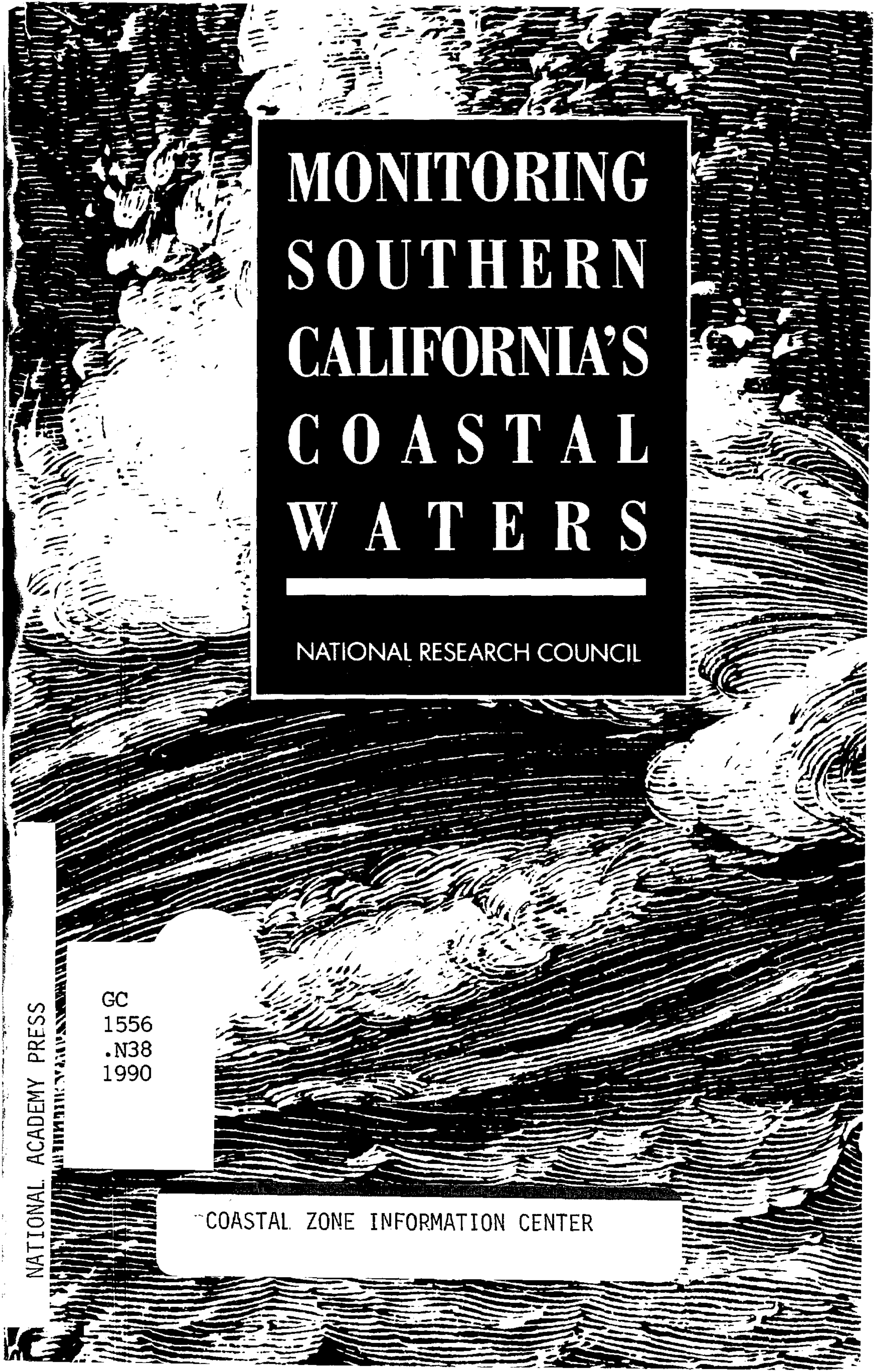

MONITORING SOUTHERN CALIFORNIA'S COASTAL WATERS

NATIONAL RESEARCH COUNCIL

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MONITORING SOUTHERN CALIFORNIA'S COASTAL WATERS

Panel on the Southern California Bight of the
Committee on a Systems Assessment
of Marine Environmental Monitoring

Marine Board
Commission on Engineering and Technical Systems
National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competence and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

PURPOSE

In 1987, the Marine Board of the National Research Council established the Committee on a Systems Assessment of Marine Environmental Monitoring. The committee's goal was to identify how monitoring contributes to environmental management, to determine why monitoring does not always produce useful information, and to recommend how more effective monitoring programs could be designed. The committee decided to carry out three case studies: the Chesapeake Bay, the Southern California Bight,[1] and particulate dispersion.

The following goals were established for this case study:

- to assess the design of monitoring programs in Southern California in terms of their technical components and linkages to relevant policy issues;

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[1] The purpose of this case study was to conduct an overall review and assessment of marine monitoring in the Southern California Bight. Although there is a long tradition of monitoring in the bight, there is widespread concern that intensive monitoring activities are not efficient and that the information that results is not sufficiently used for decision making by governmental agencies. There is also concern that monitoring does not produce a readily accessible, coherent picture of conditions in the bight's marine environment. Accordingly, this study examines monitoring as a system that includes both institutional and technical aspects, then recommends possible improvements to this system. This study thus concentrates on the interface between technical or scientific issues and institutional and policy issues. It does not, other than for illustrative purposes, attempt to describe environmental impacts or actual conditions of marine waters and living resources in the bight.

• to use the assessment to develop guidance for future monitoring practice and institutional frameworks in the region; and

• to assess whether monitoring meets society's needs as manifested in regulations, public opinion, and scientific research.

In pursuit of these goals, this study accomplishes four main objectives:

1. it describes the natural environmental setting, including the physical setting and sources of environmental pollutants and habitat change;
2. it reviews the regulatory and institutional framework, including monitoring responsibilities in the government, academic, and public sectors;
3. it discusses the evolution of monitoring and current monitoring activities in the bight; and
4. it analyzes current monitoring practice in the context of the first three objectives and describes a conceptual framework for improved monitoring.

In combination, these objectives define the overall environmental, regulatory, historical, and institutional framework within which this study assesses monitoring in the bight. The emphasis is on systematic use by regulatory and management agencies of the data collected and not on the technical adequacy of individual collection activities.

METHODS

The Committee on a Systems Assessment of Marine Environmental Monitoring established a case study panel to pursue the goals and objectives described above. The case study panel performed much of its work through a series of fact-finding meetings held throughout Southern California to seek viewpoints from the monitoring community. A planning meeting was attended by panel members, representatives of the California state and regional water quality boards, the U.S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration, municipal dischargers, and various research groups. This initial meeting achieved three results:

1. members identified important issues for the panel to investigate,
2. prepared a list of knowledgeable experts who would be invited to make presentations to the panel about these issues, and
3. specified background information needed for the panel's deliberations.

The Southern California Coastal Water Research Project prepared a report for the panel providing background information for each monitoring program in the bight, including detailed maps and data on sampling design, parameters sampled, sponsoring agency, relevant permits, and cost.

Experts invited to address the panel at subsequent fact-finding meetings were asked to make written and oral presentations. They were asked to consider specific questions about monitoring effectiveness and about their personal experiences with monitoring programs. As a result, the panel received information from experts knowledgeable about and experienced with a variety of issues, including fisheries management, the relationship of large-scale ecological processes to monitoring objectives, institutional relationships, public health, nonpoint sources of pollution, legal and regulatory requirements, wastewater treatment, thermal discharges from coastal power plants, public perceptions and interests, marine science, and monitoring design and implementation. In addition, some panel members made field visits in the region. At the conclusion of these fact-finding sessions, the panel held further meetings to discuss the structure and content of the case study report and to review and discuss draft material.

ORGANIZATION

This case study is organized into seven chapters:

Chapter 1 — The Southern California Bight provides a basic description of the geography, hydrology, water quality, climate, habitats, and natural resources of the area. It also describes land use patterns and economic activities.

Chapter 2 — Sources of Pollution and Habitat Change discusses major activities that result in pollution and habitat change, such as oil exploration and production, municipal and industrial wastewater discharges, power plant thermal discharges, stormwater and surface runoff, aerial fallout, and ocean dumping. It also contains a discussion of the characteristics of the resultant pollutants and their concentrations in the environment.

Chapter 3 — Regulatory Framework and Public Concerns sets forth the basic state and federal regulatory framework (water quality control, public health and safety, and natural resources protection) and the concerns and perceptions of the public about certain policy objectives for the bight.

Chapter 4 — Monitoring and Research Programs in the Southern California Bight discusses the relationship between research and monitoring and the general types of monitoring applied in studies of the bight. It characterizes the roles of government and of the private sector in these activities.

Chapter 5 — A Framework for the Analysis of Monitoring sets forth in general terms the theoretical objectives for a monitoring program and discusses in detail a conceptual framework that will ensure that the objectives are achieved.

Chapter 6 — Analysis of Monitoring Efforts examines specific aspects of certain monitoring efforts in the bight and evaluates the results in light of the conceptual framework and the societal expectations in Southern California. Recommendations for change are set forth in this chapter.

Chapter 7 — Conclusions and Recommendations sets forth the committee's conclusions and recommendations.

THE STUDY'S AUDIENCE

This study was requested by the parent Committee on a Systems Assessment of Marine Environmental Monitoring. Its findings and conclusions and the underlying discussion are an important source of information for the work of that committee. However, because of high interest in the condition of the environment and marine monitoring in Southern California this report will be of substantial interest to parties in that region.

Although environmental monitoring is most often considered to be within the exclusive domain of the scientific community, successful design and use of environmental monitoring depends on a system that reaches beyond scientists. The general public and interest groups have substantive questions about the condition of the marine environment that monitoring must address. Political leaders and policy makers need to make tough decisions about the allocation of monetary resources to particular control strategies, and monitoring results provide information upon which their success may be documented. Public and private managers must implement control programs and be able to predict as well as determine their success or failure on the basis of monitoring information. Finally, the scientific community is vital to the appropriate design and implementation of monitoring programs.[2]

This study, based on an examination of the monitoring system as a whole, makes recommendations about marine monitoring that respond to the needs and responsibilities of all these interests. Thoughtful consideration, debate, and (undoubtedly) modification can contribute to the evolution of marine monitoring in Southern California to make it a strong component of the overall program of environmental protection and restoration.

[2]The incorporation of relevant scientific knowledge in monitoring programs helps ensure that important questions will be properly addressed. Appropriate scientific analysis of monitoring results will also increase understanding of how the marine environment functions and responds to human impacts.

Acknowledgments

The Panel on the Southern California Bight would like to express its gratitude to a number of individuals whose assistance has been invaluable in the development of this report. The committee thanks Dr. Jerry M. Neff for his efforts as rapporteur. Appreciation is also conveyed to Jack Anderson and staff scientists at the Southern California Coastal Water Resources Project for providing the committee with the background document *A Historical Review of Monitoring in the Southern California Bight*, as well as a wealth of additional assistance. Brock Bernstein worked long and hard to shape the final report.

Many thanks also to the following individuals for their valuable input to the report: Blake Anderson of the Orange County Sanitation District, Gary Davis of the National Park Service, Dorothy Green of Heal the Bay, Robert Grove of Southern California Edison Company, Janet Hashimoto of the Region IX office of the Environmental Protection Agency, George Jackson of Scripps Institution of Oceanography, Burton Jones of the University of Southern California, Edward Liu of the Santa Ana Regional Water Quality Control Board, John McGowan of Scripps Institution of Oceanography, John Melbourn of the San Diego Department of Health Services, Richard Methot of the National Marine Fisheries Service, Robert Miele of the County Sanitation District of Los Angeles, John Mitchell of the Los Angeles Department of Public Works, Paul Papanek of the Los Angeles County Department of Health Services, John Stephens of Occidental College, and Ken Wilson of the California Department of Fish and Game.

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Finally, a special thanks to the state and local representatives of California whose concern for the region's coastal ocean environment and support for this project allowed this endeavor to transpire: Susan Hamilton of the city of San Diego, Irwin Haydock of the Los Angeles County Sanitation District, Robert Montgomery of the city of Oxnard, Michael Moore of the Orange County Sanitation District, John Norton of the California State Water Resources Control Board, Jan Stull of the Los Angeles County Sanitation District, Frank Wada of the Hyperion Treatment Facility, and Craig Wilson of the California State Water Resources Control Board.

Contents

Executive Summary

With nearly 15 million people in the region, Southern California's coastal ocean[1] is coming under increasing environmental stress. There is little coastal space that is not subject to some form of development or resource utilization—including oil extraction, commercial and recreational fisheries, municipal and industrial wastewater discharge, ship traffic, and recreation.

There is in the region a broad public perception of environmental degradation. This is set against a backdrop of extraordinarily complex natural ecosystem processes that are not fully understood, extensive public and private efforts to protect and restore environmental systems, and great public concern for the environment.

Environmental management efforts have included numerous marine environmental monitoring programs. These efforts have been both extensive (for example, the long-term time-series resource assessments of the California Cooperative Oceanic Fisheries Investigation [CalCOFI]) and elaborately detailed, such as the monitoring programs for municipal waste water and electric power plants. The total amount of money and effort expended by public utilities, private industry, and government agencies in marine monitoring efforts in Southern California is conservatively estimated at well over $17 million annually.

[1] This report addresses the region known as the Southern California Bight, the oceanic region from Point Conception, California to Mexico and seaward from the coast to the California Current.

As part of a larger assessment of marine environmental monitoring, the National Research Council analyzed the effectiveness of marine environmental monitoring in the Southern California Bight. The study committee found an extensive system of monitoring of environmental conditions in the bight, but also widespread concern that the system is not efficient and that its products are not sufficiently used for decision making.

The committee found that because monitoring in the bight is predominantly organized around discharge permits responding to water quality regulations, there is a fragmented approach to assessing environmental quality. There are deficiencies in monitoring for public health concerns and nonpoint discharges. Also, there are no existing formal mechanisms for integrating the wide array of monitoring activities and their findings; as a result, it is difficult—if not impossible—to present a coherent picture of the state of the bight as a whole. There is a glaring need for a regionwide monitoring system and for effectively reporting findings to the public, the scientific community, and policy makers.

In response to these findings, the committee recommends that a regional monitoring program be established that would address public health impacts, natural resources and nearshore habitat trends, nonpoint source and riverine contamination, and cumulative or areawide impacts from all contaminant sources.

A regional program should involve participation by the public and scientific communities at local, state, and federal levels and should include built-in mechanisms to communicate its conclusions to regulatory agencies and the public, the committee noted. It should also include review mechanisms and allow easy alteration or redirection of monitoring efforts, whenever justified by monitoring results or other information. Anticipated benefits from a regional program would include:

- *greater cost efficiency* through use of standardized sampling, analysis, data management, and coordination of effort;
- *ability to address specific questions* about environmental conditions and resources and to alter or redirect monitoring efforts as needed; and
- *more effective use of monitoring information* in decision making by ensuring better communication with and involvement by the public and scientific community.

Implementing a regional program will require coordination among local, state, and federal agencies and the integration of their regulatory, data, and management needs. Only through an integrated systemwide approach can important environmental and human health objectives identified by society be successfully attained: ensuring that it is safe to swim in the ocean and eat local seafood, providing adequate protection for fisheries and other living resources, and safeguarding the health of the ecosystem.

1
The Southern California Bight

No system of marine monitoring exists in the abstract. Monitoring occurs in specific geographic regions that have particular qualities derived from their natural characteristics and processes. The marine environment in turn is affected by the human activities that take place in and adjacent to it. Understanding the strengths and weaknesses of monitoring in the Southern California Bight therefore requires a basic knowledge of the physical setting and human activity within it.

This chapter describes the physical setting of the Southern California Bight: its bathymetry, drainage basin, circulation and ocean-ography, climate, and hydrology. It also describes the natural habitats and resources of the region and the land use and economic activities of the adjacent coastal areas. Chapter 2 will describe in greater detail the sources and types of habitat change and pollutant loadings to the marine environment that stem from human activities in the bight.

PHYSICAL SETTING

The Southern California Bight is bounded on the north, east, and southeast by a long curve of the North American coastline extending from Point Conception in Santa Barbara County, southeast 357 mi to Cabo Colnett, Baja California in Mexico (Figure 1-1). It is bounded to the west by the California Current, which flows southeasterly approximately parallel to the coast and the edge of the continental shelf. The bight system includes more than 37,000 mi^2 of ocean and approximately 8,700 mi^2 of adjacent coastal areas draining into it.

Bathymetry

The bathymetry underlying the Southern California Bight has many features unique to the continental shelf surrounding the United States. For this reason the area was named "continental borderland" by Shepard and Emery (1941). Topographic features in the continental borderland and adjacent mainland drainage basin are summarized in Table 1-1.

The waters of the bight overlay an alternating series of 2,000- to 8,000-ft-deep basins and surfacing mountains that form 9 offshore islands or island groups and several large submerged banks and seamounts. Nearshore, 12 large submarine canyons influence movement of sediments and other materials deposited on the bottom. There are also 32 submarine canyons on the continental slope bordering the U.S. portion of the bight, including 20 canyons that cut into the mainland shelf (Emery, 1960). Offshore, there are 18 marine basins, 3 of which are essentially anoxic.

These submarine canyons and deep basins are important sites of accumulation of fine-grained sediments and particulate materials from land runoff, ocean discharges, and ocean dumping. An important feature throughout the bight is that deep water is close to shore. All slopes are steep, ranging from 5 to 15 percent. Island and mainland shelves are narrow, from less than 0.6-mi wide to a maximum of 12.5-mi wide. The mainland and island shelves constitute only about 11 percent of continental borderland area; marine basins cover about 80 percent of the borderland area.

The most important embayments of the mainland shelf are Santa Monica Bay and San Pedro Bay (separated from each other by the prominent and steeply sloping Palos Verdes Peninsula and shelf), San Diego Bay, and Todos Santos Bay in Baja California. Although no true estuaries penetrate the mainland coast, there are at least 26 wetland systems in coastal lagoons and at the mouths of transient streams and rivers in the U.S. portion of the bight (Figure 1-2)(Zedler, 1984). The total area of these coastal wetlands is only about 129 mi^2, an estimated 25 percent of the area they encompassed when the first Europeans arrived in Southern California in the late 1500s.

Drainage Basin

The onshore mainland drainage basin of the Southern California Bight, occupied by an ever-increasing human population of nearly 15 million, is a triangle-shaped, higher elevation extension of the offshore bathymetry. It consists of nearly equal areas of mountains and basins or plains (Table

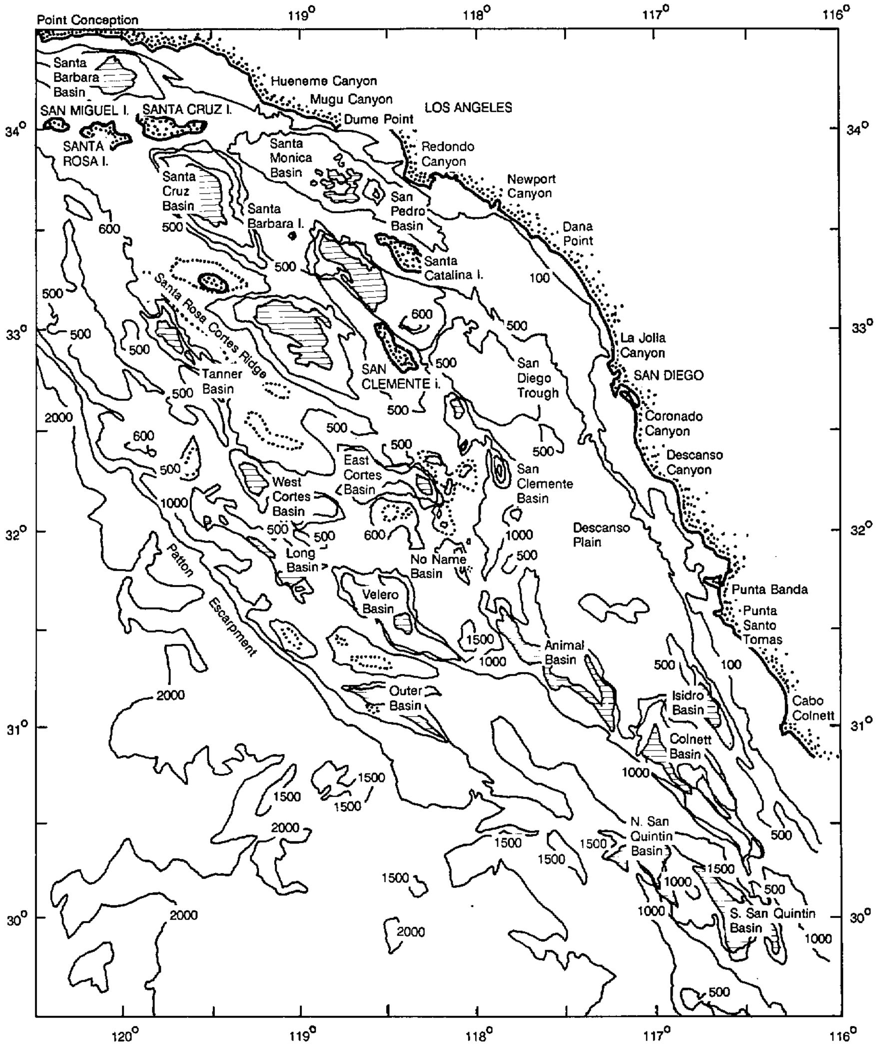

FIGURE 1-1 Bathymetry of the Southern California Bight, emphasizing its deep basins (shaded). Depth contours are shown in fathoms (1 fathom = 6 ft). SOURCE: Moore, 1969.

1-1). The rising shoreline is characterized by vertical scarps and wave-cut cliffs. There are as many as 20 raised marine terraces on land that are an extension of the 5 submerged terraces that lie at depths to 289 ft along the mainland shelf (Emery, 1960).

The drainage basin is bordered on the north by transverse (east-west ranges extending from Point Conception eastward along the Santa Monica,

TABLE 1-1 Topography and Bathymetry of the Southern California Bight Area

Feature	Area Mi²	Area % Total	% Borderland
Mainland			
mountains	4,600	10.0	---
basins and plains	4,090	9.0	---
Subtotals	8,690	19.0	---
Borderland			
islands	340	0.7	1.1
mainland shelf	1,890	4.1	6.2
island shelves	1,390	3.0	4.6
bank tops	2,420	5.3	8.0
basin and trough slopes	19,120	42.0	63.3
basin and trough floors	5,120	11.2	16.8
Continental slope	1,960	4.3	---
Abyssal seafloor	4,740	10.4	---
Subtotals	36,980	81.0	---
Totals	45,670	100.0	100.0

SOURCE: Emery, 1960.

San Gabriel, and San Bernardino mountains; and on the east by coastal ranges that continue southward down the length of the Baja Peninsula (SCCWRP, 1973). These mountain ranges separate the semiarid coastal plain from the very arid desert basins.

Because of the semiarid nature of the drainage basin and the highly seasonal pattern of annual precipitation, most of the rivers draining into the bight are small and are dry for much of the year. From north to south, the major rivers in the drainage basin are the Santa Clara, Los Angeles, San Gabriel, Santa Ana, San Luis Rey, San Diego, and Tijuana rivers (Figure 1-2). Much of the length of the Los Angeles and San Gabriel river beds and other major drainages are now lined with concrete. Most rivers have dams and debris basins constructed upstream to aid in flood control. In Southern California, there are separate systems to handle stormwater runoff and municipal wastewater flows.

Circulation and Oceanography

The western border of the Southern California Bight is marked by the California Current, which flows southeastward along the coast, continuing the clockwise geostrophic transport of water in the North Pacific Ocean (Figure 1-3). Water current regimes in the Southern California Bight are

FIGURE 1-2 Location of Southern California coastal wetlands and major rivers. SOURCE: Zedler, 1984.

complex and variable on seasonal and longer time scales. Only the general patterns will be described here. Because of the eastward indentation of the coast in the Southern California Bight, a surface counterclockwise gyre, the Southern California Eddy, breaks off the California Current and carries water northward through the central bight (Jones, 1971; Hickey, 1979). The eddy is usually well developed in summer and autumn and weak in winter and spring.

Closer to the shore along the mainland shelf, prevailing onshore (northwesterly) winds reverse this flow, resulting in a net alongshore surface flow toward the southeast at speeds of 1 to 3.3 cm/s (Lentz and Winant, 1979). Hendricks (1977) reported that the mean direction and velocity of water currents just below the thermocline are upcoast at 3 cm/s, and that this near-bottom current has a significant offshore component. Coastal currents reach maximum velocity in water depths of about 197 ft (Jackson, 1986). These complex nearshore currents are interrupted by coastal headlands and upwelling epicenters and respond to both regional and local land-sea breezes. During the afternoon, sea breezes are responsible for both cooling on land and shoreward movement of natural and man-made floating materials.

There is also a very nearshore circulation pattern caused by surf along

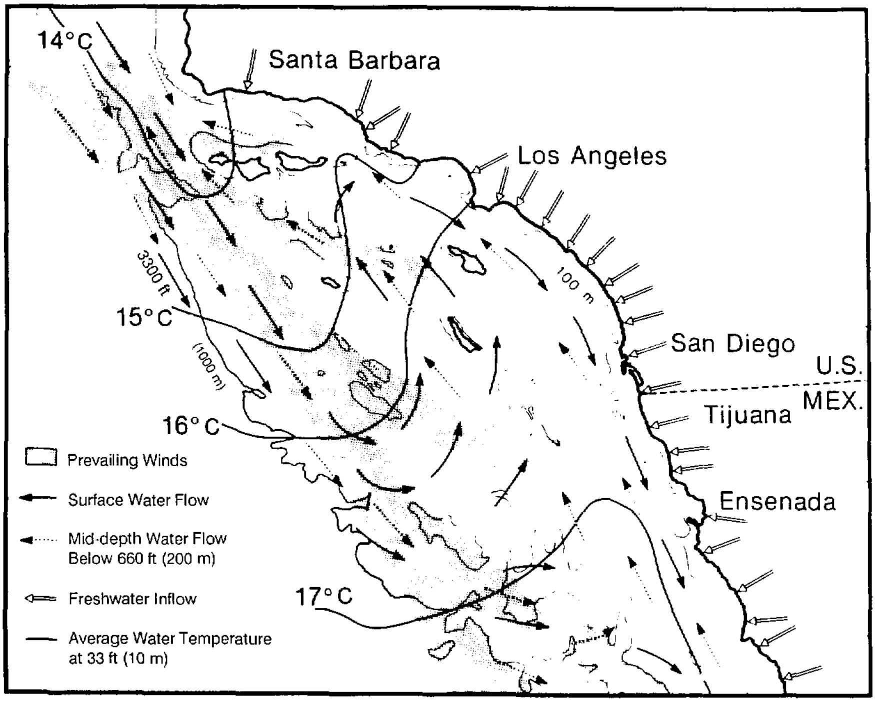

FIGURE 1-3 Patterns of nearshore bathymetry, wind, and ocean circulation in the Southern California Bight. SOURCE: Zedler and Nordby, 1986.

the beaches (Jones, 1971). The surf-driven current consists of transport alongshore inside the breaker zone to zones of outward-flowing water called "rip currents." The rip currents carry water transported inshore by the surf back offshore. This local circulation is important in beach erosion and nourishment and in transport of wastes from offshore discharges and stormwater runoff into and through recreational areas.

Below about 500 ft, there is a northwestward current flow of 25 cm/s or less inshore of the California Current (Figure 1-3). This water is of equatorial Pacific origin and has a higher temperature, salinity, and phosphate concentration and a lower oxygen concentration than the deep water in the California Current located at the same depth but farther offshore (Jones, 1971). This northward flow is weak but progressive through the deep basins and more vigorous along the mainland shelf and slope. Ordinarily, the northward countercurrent does not surface within the bight, except occasionally during the winter. This flow may surface nearshore off Los Angeles in late fall and winter and move northward as the Davidson Current, possibly as far as Vancouver Island, Canada, particularly during the periodic climatic anomalies known as "El Niño" events (described in detail later in this chapter). There is still some uncertainty about the continuity between the Davidson Current and the deep countercurrent in the bight (Hickey, 1979).

Because surface waters in the bight originate primarily from the south-flowing California Current, they are more nutrient-rich, less saline, and cooler (annual range 13° to 20°C) and undergo less seasonal temperature variation than nearshore surface waters at similar latitudes along the east coast (e.g., South Carolina and Georgia). Temperature drops with increasing water depth to about 4°C in the basins. Dissolved oxygen concentration also tends to decrease with depth, such that waters below the sill depths of the Santa Barbara, Santa Monica, and San Pedro basins are periodically or permanently anoxic (Emery, 1960). Due to anoxic conditions, bottom water and sediments in these basins are virtually devoid of higher life forms. The basins are major repositories for sediments and other particulate materials (including sludge) transported onto the shelf from the land and coastal waters.

Climate and Hydrology

The climate of Southern California is like that of the Mediterranean, with most of the precipitation occurring during winter months. Monthly mean temperature and precipitation for Los Angeles and San Diego are summarized in Table 1-2. Monthly mean temperatures in both cities vary by only about 10°C, though periodic extreme temperatures may range over about 35°C. Mean monthly precipitation ranges from near zero in June, July, and August to 2.0-3.3 in. (50 to 85 mm) in December, January, and February.

It is now clear that many environmental changes in the bight are connected more with long-term, low-frequency, interannual patterns than with seasonal cycles. Displacement of cool surface waters—including their inhabitants—in the bight by clear, nutrient-poor warm water is correlated with periodic warm-water events off the coast of Peru and in the tropical Pacific. These are the El Niño events, which occur several times per decade (e.g., 1976, 1979, 1982-1984, 1986-1987) and are characterized by warm water, a deeper surface-mixed layer, elevated sea levels, increased abundance of southern planktonic and pelagic organisms, alterations of benthic community structure, and degeneration of coastal kelp beds (Jackson, 1986). El Niño events and other long-term oceanographic changes also affect the weather in the bight. In some years (e.g., 1969 and 1982-1983) floods rule the coastal plain; in other years drought occurs (e.g., 1976-1977). In some years, there is a deep-penetrating, southerly ocean swell that mixes and resuspends mainland shelf sediments.

TABLE 1-2 Average Monthly Temperature and Precipitation in Los Angeles and San Diego, California

Parameter	Location	J	F	M	A	M	J	J	A	S	O	N	D
Temperature °C	Los Angeles	13	14	15	16	18	20	22	23	22	19	17	14
	San Diego	13	14	15	16	18	19	21	22	21	19	16	14
Precipitation mm	Los Angeles	60	85	60	30	6	2	0	0	7	13	26	79
	San Diego	51	55	40	20	4	1	0	2	4	12	23	52

SOURCE: Rudloff, 1981.

Crustal blocks between numerous faults move with alarming frequency, causing earthquakes. Oil and tar continuously ooze from shelf and island seeps, periodically creating large marine oil slicks. During some droughts, brush fires, fed by northeasterly Santa Ana winds, spew plumes of ash and soot onto the adjacent sea and coastal plain. Landslides and subsidence are common and predictable in certain hill and bluff areas. In short, the predominantly mild sunny climate of the Southern California Bight area does not reflect the major impacts of occasional meteorological and geological events.

Fresh water enters the bight from a variety of sources. Riverine runoff from rain and melting snow is very seasonal. Much of the water imported from Northern California through the California Aqueduct, from the high Sierra Mountains through the Owens Valley Aqueduct, and from the Colorado River through the Metropolitan Aqueduct (Table 1-3) eventually finds its way to the bight through land and subterranean runoff and discharges of waste water. The cost of wastewater disposal from municipal and industrial activities is 5 to 10 times the cost of supplying the water (World Bank, 1980). Disposal costs for agricultural drainage are about half those of water supply, unless treatment is required.

Because of the semiarid climate of the bight drainage basin, the volumes of water entering the bight from wastewater discharges are comparable to those from riverine and storm drain inputs. Because stormwater flow is more variable than wastewater flow, in dry seasons and years wastewater flow far exceeds that of storm water. For example, the mean treated wastewater flow to Santa Monica Bay between 1967 and 1982 was 346 million gal/day, with the annual mean increasing from 320 million in 1967 to 379 million gal/day in 1982 (Garber, 1987). Stormwater flow to Santa Monica Bay over the same period averaged 143 million gal/day and ranged from 51 million gal/day in 1972 to 400 million gal/day in 1969. However, nearly all of this stormwater flow occurred during and shortly after a few winter storms each year. Thus, the only continuous freshwater flow to the bight is treated municipal waste water. This includes primary, secondary, and tertiary treated sewage discharged directly to the ocean from coastal treatment plants and tertiary treated sewage discharged from inland treatment plants to Southern California rivers and streams. This pattern of freshwater input to coastal waters is quite different from that in much of the rest of the coastal United States, where riverine and stormwater flow far exceeds wastewater flow.

HABITATS AND NATURAL RESOURCES

Natural habitats and resources characteristic of the Southern California Bight include abundant deep water close to shore, extensive coastal

TABLE 1-3 Water Supply and Demand in Southern California

Parameter	1990	2010
Estimated population (millions)[a]	15.29	17.75
Water supply (millions of gal/day)		
local	1,955	1,955
reclaimed	143	152
Los Angeles Aqueduct	375	375
Colorado River	714	420
state water project	1,143	1,295
Total supply	4,330	4,147
Water utilization (millions of gal/day)		
residential	1,607	2,090
commercial	473	643
industrial	330	411
public[b]	411	464
agricultural	794	580
Total demand	3,615	4,188
Supply minus demand	+ 715	- 41
Per capita demand (gal/day)		
residential	105	118
commercial	31	36
industrial	22	23
public[b]	27	26
agriculture	52	30
Total per capita demand	237	233

[a]California Department of Finance data, assuming half of total increases in county projections will occur in coastal drainage area.
[b]Includes unaccounted for water.

SOURCE: California Department of Water Resources, 1987; Los Angeles Department of Water and Power, 1985-1986 Annual Report; State Water Contractors, Bay-Delta Hearings, June 1987, SWC Exhibit Numbers 3, 6, 13, 17, 76.

and offshore oil reserves, commercially or recreationally valuable fish and shellfish stocks, wildlife breeding and overwintering areas, kelp beds, beach and water recreation areas, and a climate tempered by the special oceanographic processes reviewed above.

As a result of the local oceanographic regime, particularly the Southern California Eddy, the bight is an enclave of communities of marine life specific to the area, except during El Niño years. It is also a trap for warm water and natural and anthropogenic materials entering the area from land, sea, and air.

Six species of seals and sea lions and the northernmost Pacific population of pelicans breed on several islands. Regional populations of porpoises occur in the bight, and the entire population of gray whales spends a portion of fall and winter there during its annual migration between the Bering Sea and Baja California.

Commercially exploitable stocks of anchovies, sardines, and mackerel spawn and grow primarily in the bight, as do bass, croakers, flatfishes, and rockfishes. Mariculture operations have been established in Agua Hedionda Lagoon in San Diego County (mussels and oysters) and in the Santa Barbara Channel (oysters, mussels, and scallops) (California Department of Health Services, 1988b). Deeper waters of the bight host a diversity of mesopelagic fishes that spend part of their life cycle in surface waters. The benthic fauna of the continental shelf, especially polychaetes and crustaceans, are very diverse and constitute an important food source for many fish species.

Rocky intertidal and subtidal areas, which cover large areas of the shoreline of the bight, host a rich diversity of epifauna (snails, mussels, crabs, etc.) and attached seaweeds. Beds of the giant kelp Macrocystis pyrifera, which attach to the bottom and can grow to over 164 ft in length, extend along the coast of the bight. There are 33 locations in the bight between Point Conception and San Diego where kelp beds are found at least periodically at water depths ranging from 20 to 65 ft. From the 1930s to 1979, individual kelp beds occupied up to 2,720 acres, with the total area occupied by kelp beds in the range of 12,000 to 15,000 acres (Foster and Schiel, 1985). The size and distribution of kelp beds varies spatially and temporally in response to changes in natural and anthropogenic conditions. Natural changes in surface water temperature and nutrient concentrations associated with El Niño events, and possibly with longer-term ocean warming trends, have resulted in declining kelp beds in some areas, and winter storms like those of 1983 and 1987 can devastate large kelp beds. These storms probably are the most important factor influencing the condition and areal extent of kelp beds, but human activities—such as kelp harvests, boat traffic, and possibly wastewater discharges at Palos Verdes and Point Loma—have also affected local giant kelp beds.

LAND USE AND ECONOMIC ACTIVITY

A combined U.S.-Mexico population of about 15 million people lives in, works in, and enjoys the coastal climate and resources in the drainage basin of the Southern California Bight. The population in this area has increased steadily since the 1890s.

Although once primarily an agricultural region, Los Angeles and adjoining counties now comprise the manufacturing, petrochemical, commercial, and aerospace center of western North America. There also are large military bases throughout the area. Accessible land space is now largely occupied by several hundred cities, hundreds of square miles of residential areas, highways, airports, and citrus groves.

Because of current land and water use practices, the entire region is heavily dependent on water diverted from northern and eastern California and the Colorado River system (Table 1-3) that would otherwise flow into the San Francisco Bay and delta area, Mono Lake, the Owens Valley east of the Sierra Mountains, and the Gulf of California. Water utilization in Southern California is projected to increase in the next 22 years due to an expected 16 percent increase in population, and despite a projected slight decrease in per capita consumption of water (Table 1-3). However, at the same time, total freshwater supply will decrease due to partial loss of water rights to the Colorado River. Disputes over other water sources continue, and these supplies are by no means assured for future use by Southern California. As a result, demand will be greater than supply by the year 2010, requiring increased conservation and on-site reclamation.

As described in "Climate and Hydrology," the base flow for most of the Southern California drainage system is now derived from treated waste water (see Chapter 2, Figure 2-2 for further detail). Secondary or tertiary treated sewage from inland treatment plants makes up much of the permanent flow of the Los Angeles, San Gabriel, Rio Hondo, and Santa Clara rivers in Los Angeles and Ventura counties. These discharges, as well as other NPDES-permitted (National Pollutant Discharge Elimination System) flows to the rivers are strictly regulated to protect water-contact recreational areas. However, storm drains and nonpoint source runoff to rivers are not regulated. Such flows may contain elevated concentrations of chemical contaminants and pathogens.

Highways are the principal basis of transportation in Southern California. Heavy manufacturing (metals, chemicals) is located near the coast and within convenient access to well-developed port facilities in Los Angeles, Long Beach, and San Diego harbors. The most active shipping, shipbuilding, and maintenance in western North America occurs in the combined complex of Los Angeles-Long Beach harbors; and military activities occur around Mugu Lagoon and Anaheim Bay (munitions), along the north San Diego County coastline (Camp Pendleton Marine Base), and at San Clemente Island (target practice). The harbors of Long Beach and San Diego were principal Pacific staging areas during World War II (1941-1945) and continue today as active naval and ship building bases.

Oil extraction has occurred for eight decades within and offshore of coastal city limits of Goleta, Carpinteria, Ventura, Oxnard, Santa Monica, Redondo Beach, Wilmington, San Pedro, Long Beach, Seal Beach, and Huntington Beach. Terminal Island and adjoining areas sank up to 30 ft (Allen, 1973) when oil was pumped out in the 1930s and 1940s. Offshore oil extraction from shore-based facilities began near the turn of the century along the Santa Barbara Channel and slightly later in southern Los Angeles and Orange counties. Oil production from offshore platforms began 35 years ago on nearby shelves (1 to 3 mi from shore) and now extends nearly to the shelf break. Proposals for more extensive offshore oil exploration and development in the bight are being hotly debated because many Southern Californians consider them a great potential pollution hazard to the marine environment. An extensive shore-based infrastructure has sprung up to support offshore oil production activities—including pipelines, refineries, produced water treatment facilities, and oil terminals.

Year-round commerce, fisheries, and marine recreation, combined with steady population growth, have resulted in constant development of harbors, marinas, and coastal home sites in Southern and Baja California. The region's 30,000 to 40,000 pleasure boats are concentrated primarily in Marina del Rey on Santa Monica Bay, in the new Los Angeles City Cabrillo Marina, in Alamitos Bay, Long Beach Marina, Huntington Harbor, Balboa-Newport harbors, northern San Diego Bay, and Mission Bay; and secondarily in marinas at Oceanside and Dana Point, and in Oxnard, Ventura, and Santa Barbara. Because pleasure boats are sources of fuel leaks and toxins from antifouling paints, they constitute a potential environmental problem that has not yet been quantified.

Fourteen coastal electric power plants in Southern and Baja California supply much of the region's power and recirculate nearly 11 billion gal/day of nearshore seawater, some of which controls circulation in harbors and marinas. Most generating plants operate on oil delivered by offshore tankers, and oil spills occasionally result from accidents involving tankers supplying fuel to plants in Southern and Baja California (e.g., Nishikawa-Kinomura et al., 1988). For example, in Los Angeles/Long Beach harbors where most of the tanker terminals are concentrated, an estimated 1.3 million gal of oil and fuels have been spilled since 1976; in the Santa Barbara Channel, since 1969 over 3.5 million gal of oil have been spilled from two oil platforms and a tanker collision. The San Onofre Nuclear Generating Station (SONGS) is the only nuclear plant on the coast of the bight.

Much of the region's 1.5 billion gal/day of raw sewage is collected via large-scale intercity networks of trunklines and transferred to 13 coastal Publicly Owned Treatment Works (POTWs) where effluent is subjected to primary, advanced primary, and in some cases secondary treatment and discharged to the ocean via submarine outfall diffusers at depths from 65 to 328 ft. Tertiary treatment currently reclaims almost 150 million gal/day of water, and there is a future potential to reclaim 0.5 billion gal/day. The reclaimed water is used for landscape irrigation, groundwater recharge, industrial processing, and control of saltwater intrusion into coastal aquifers. Storm water is completely separated from sewage in all major systems, but overflows occasionally occur. However, as discussed above, several POTWs discharge secondary or tertiary effluent to Southern California rivers for transport to the ocean. For example, the Los Angeles and San Gabriel rivers each receive about 100 million gal/day of treated waste water. Percolation of storm water into aging sewer lines during storms occasionally overwhelms the system, resulting in release of raw sewage to the bight.

The least developed areas of the bight include the northwesternmost 37-mi stretch of coast between Point Conception and Santa Barbara, the 12-mi coastline of Camp Pendleton in northern San Diego County, the central San Diego County coastline, the Channel Islands, and the Baja California coast south of Todos Santos Bay, near Ensenada.

In summary, there is little coastal space that has not been subject to construction, mineral extraction, or other forms of resource utilization. There is keen competition for coastal space, access, and resource utilization and, as a consequence, conflict among the many potential users. The California Coastal Commission, formed as a result of a 1969 ballot initiative, resolves conflicts related to multiple uses of the coastal zone.

SUMMARY

There are several natural and anthropogenic features of the Southern California Bight that are important for the consideration of environmental impacts and marine monitoring in the bight. The continental shelf throughout the bight is very narrow, and deep water exists near shore as a result of the bight's many submarine canyons and basins. The bight's western border is defined by the California Current, and the complex pattern of currents, eddies, and counter currents creates enclaves of indigenous biological communities. Many important environmental processes and changes are related more to long-term, low-frequency, interannual patterns than to yearly or seasonal cycles. The semiarid drainage basin of the bight receives sparse rainfall and much of the human activity in the area depends on imported water. As a consequence, many area rivers are dry much of the year, and wastewater flows constitute the only continuous freshwater input to the bight. Wastewater flows from treatment plants exceed natural flows from runoff and storms. Because waste water and storm water are managed by separate systems, however, the bight does not have the combined sewer overflow problems that characterize other coastal areas in the United States.

The Southern California Bight contains rich biological resources that support diverse commercial and recreational activities. In addition, many marine mammal species, including the entire gray whale population, spend part or all of each year in the bight.

Finally, as a result of Southern California's large population and attendant intense economic and recreational activity, there is little coastal space that has not been subject to construction, mineral extraction, or other forms of resource utilization. This activity has resulted in extensive habitat change and large and varied inputs of contaminants to the bight. These are reviewed in the next chapter.

2
Sources of Pollution and Habitat Change

Southern Californians have lived with contaminants and habitat change since before 1572, when Juan Cabrillo's ship entered the Bahia de Los Fuomos (Bay of Smokes, now Santa Monica Bay) and witnessed coastal Indians sealing their boats with tar from local oil seeps. Today, the ever-growing population of about 15 million has dramatically increased its utilization of marine resources and the types and amounts of contaminants produced and released to the Southern California Bight. These contaminants stem from sewage discharges, aerial fallout, land runoff, industrial and munitions disposal, dredged material disposal, and thermal enrichment. As a result, some of the bight's coastal waters and underlying sediments have become polluted and marine resources have been degraded.

This chapter describes the major human activities that have impacted the bight's marine environment and discusses in detail the various contaminants that may derive from these activities. They include wastes from petroleum exploration and production, radionuclides, pathogenic organisms, waste heat, organic matter, nutrients, trace metals, and synthetic organic chemicals. Since this chapter is intended to provide an overview of contamination, sources and amounts of contaminants—rather than their environmental impacts—are emphasized, followed by a brief overview of the regional and local environmental problems that have attracted public, regulatory, and scientific attention.

TABLE 2-1 Total Estimated Average Daily Wastewater Flows in 1984-1985 to the Southern California Bight from Seven Large Publicly Owned Sewage Treatment Plants

Outfall Name	Discharge (millions of gal/day)		
	Primary	Secondary	Sludge
Oxnard, Ventura County Sanitation Districts	None	18	None
Hyperion, Los Angeles City Bureau of Sanitation	292	97	4[a]
Joint Water Pollution Control Plant, Los Angeles County Sanitation Districts	183[b]	179	None
County Sanitation Districts of Orange County	94	138	None
South East Regional Reclamation Authority	12.5	None	None
Encina Water Pollution Control Facility	11	5	None
Point Loma, City of San Diego	156	None	None
Totals	742	443	4
Grand total			1,190

[a]Terminated, per court order, November 1987.
[b]Advanced primary, which removes 80 percent of solids (primary removes 60 percent).

SOURCE: SCCWRP, 1986a.

MAJOR SOURCES OF CONTAMINANTS

Sixteen municipal sewage treatment plants discharge partially treated sewage directly into the U.S. waters of the Southern California Bight. In addition, more than 230 million gal/day of treated sewage is carried by coastal rivers and storm drains from inland Publicly Owned Treatment Works (POTWs). In 1985, over 1.2 billion gallons of effluent were discharged daily into the bight's coastal waters by seven major municipal wastewater dischargers (Table 2-1 and Figure 2-1).

Over the years, major strides have been made to decrease the amounts of total solids and contaminants in the discharges, even as the total volume of sewage discharges has increased (Figure 2-2) (Southern California Coastal Water Research Project [SCCWRP], 1986a; Summers et al., 1987).

This has been accomplished primarily by a gradual but progressive shift over the last 100 years from discharge of raw sewage, to discharge of primary treated sewage, to discharge of advanced primary and secondary treated sewage (Figure 2-3); by a gradual phaseout of pipeline discharge of sludge; and, most important, by source control. In 1985, 62.4 percent of the total sewage from the seven major dischargers received primary treatment, 37.2

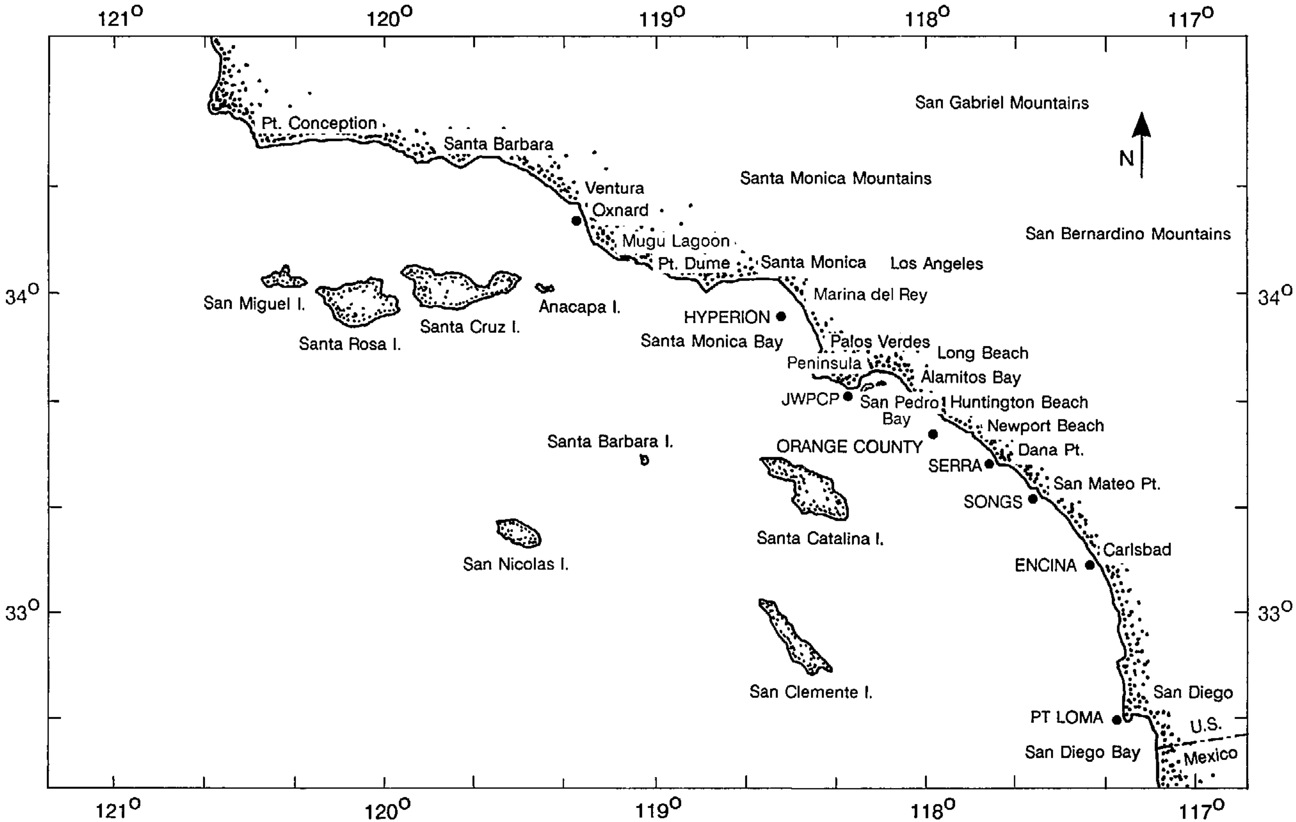

FIGURE 2-1 Major dischargers into the Southern California Bight.

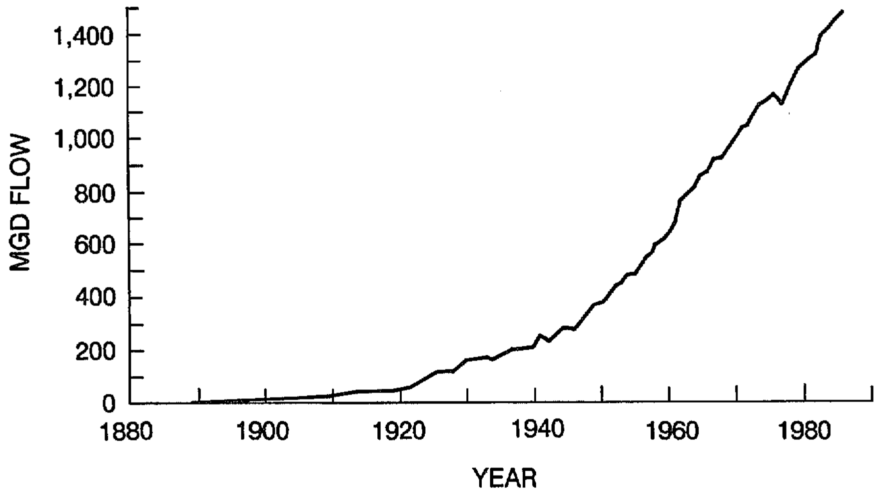

FIGURE 2-2 Municipal wastewater flow (millions of gallons per day) for the years 1890 to 1990 through sewage treatment facilities in Southern California that discharge treated wastewater to the Southern California Bight. SOURCE: Summers et al., 1987.

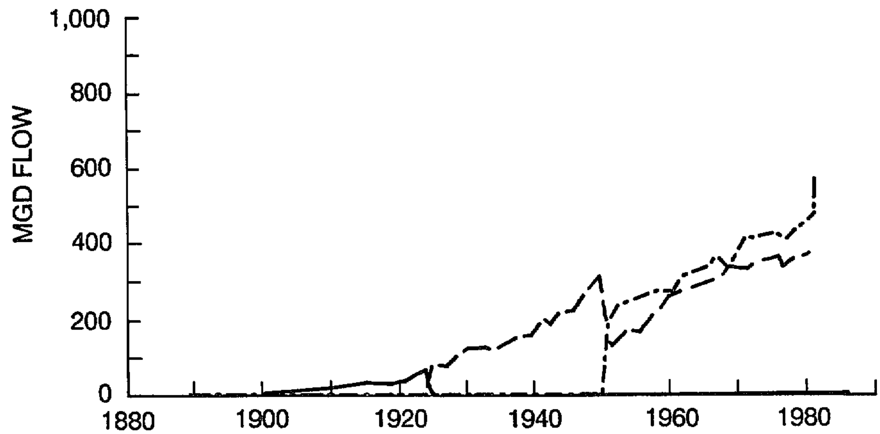

FIGURE 2-3 Annual municipal wastewater flow to the ocean (millions of gallons per day) by treatment level in Los Angeles County, California (raw, —; primary, - - -; secondary, -.-.-.). SOURCE: Summers et al., 1987.

percent received secondary treatment, and 0.4 percent was anaerobically digested sewage sludge, discharged from the Hyperion Treatment Plant.

The Hyperion Treatment Plant operated by the city of Los Angeles discharged sludge from 1957 through 1987 via an ocean outfall in 318 ft of water at the head of the Santa Monica submarine canyon in Santa Monica Bay. The County Sanitation Districts of Los Angeles discharges the liquid phase produced by dewatering sludge by centrifugation. Prior to 1983, this waste water contained high concentrations of solids (sludge). In 1983, new centrifuges with improved solids recovery (90 to 95 percent) came on line, resulting in a significant reduction in solids emissions. The Sanitation Districts of Orange County ceased discharging sludge to the ocean in 1984. The city of San Diego's Point Loma Treatment Plant discharged sludge to the ocean only during emergencies, when a pipeline to the Mission Bay drying beds was inoperative.

Most sewage sludge is now disposed of onshore. However, the shift from primary to secondary treatment results in a substantial increase (approximately double) in the volume of sludge generated. Although it has been suggested that various ocean disposal options may be reconsidered for handling increasing volumes of sludge (Conrad, 1985), ocean dumping is no longer an option. Other possible uses of sludge are composting, use in industrial processes, and landfill cover.

Because the Southern California Bight region is semiarid, design requirements for storm water and sanitary sewer-handling systems are quite different. As a consequence, storm drainage and sanitary sewer systems have been separate throughout the history of the region, unlike nearly all other major U.S. coastal urban areas. Surface runoff from land enters the bight through 150 natural streams (Figure 1-2) and 18 hydrologic units. In addition, there are several major channels in Los Angeles, Orange, and San Diego counties for stormwater runoff. In the Los Angeles County Flood Control District alone, there are 2,000 mi of underground drains, 500 mi of open channels, and 50,000 catch basins. Most of the surface water flow of 405 million gal/day (peak value) enters the bight from 20 major streams and channels, mostly in pulse inputs during winter storms. There are, in addition, hundreds of individual storm drains that discharge directly to the ocean.

Harbors and marinas are sources of local and, in some cases, regional contaminant inputs to the bight. For instance, a 1973 study (SCCWRP, 1973) indicated that 80,000 gal of antifouling paints containing 180 tons of copper were applied annually to many of the 35,000 recreational boats and numerous commercial and naval vessels that use these facilities. Most of this copper eventually dissolved into the water. In recent years, organotin compounds have largely replaced copper in antifouling paints, creating an even greater problem because of their high toxicity to marine animals. San Diego Bay and Los Angeles and Long Beach harbors are contaminated with organotins, with measured concentrations in the water column in the range of 0.02 to 0.93 mg/liter, and concentrations in sediments at least a hundredfold higher (Grovhoug et al., 1986). Many power boats and

TABLE 2-2 Estimated Annual Inputs (Metric Tons/Year) of Trace Metals to the Southern California Bight

Metal	Municipal* waste water 1976	Dry fallout 1975	Storm runoff 1971-1972	1972-1973	Thermal discharge 1977
Cadmium (Cd)	45	0.84	1.2	2.8	0.3
Chromium (Cr)	593	6.6	25	60	0.6
Copper (Cu)	507	31	18	42	2.1
Lead (Pb)	190	240	90	210	0.8
Mercury (Hg)	2.6	---	---	0.43	---
Nickel (Ni)	307	12	17	41	0.7
Silver (Ag)	20	0.06	1.1	2.6	---
Zinc (Zn)	1,060	150	101	240	1.8

*Before initiation of industrial wastewater source control.

SOURCE: Young et al., 1973, 1978.

submerged metal structures are equipped with sacrificial anodes designed to help prevent corrosion of submerged metal structures. These anodes leach aluminum, copper, and zinc.

Along the coast of the bight, there are 14 steam electricity generating stations that use sea water for once-through cooling. Total cooling-water flow from the plants is about 10.7 billion gal/day. The San Onofre Nuclear Generating Station (SONGS) alone has a base flow of about 2.4 billion gal/day. These flows introduce heat and small amounts of biocides (chlorine), radionuclides, and metals (Table 2-2) into the bight ecosystem. In addition, cooling-water intakes entrain large numbers of fish larvae and plankton and impinge adult fish and other marine organisms. During the special 316b study period from October 1978 through September 1980, Southern California Edison Company's eight coastal power plants impinged an average of 2.2 million fish per year, at an average total weight of 215,000 lbs (Herbinson, 1981). Fish impingement since this study period has averaged approximately half this amount. This is because surf perches, which made up a large percentage of fish impinged during the study period, decreased drastically in abundance during the El Niño periods of the 1980s and have only recently begun to reappear (K. P. Herbinson, Southern California Edison, Co., personal communication).

Other sources of contaminant inputs to the bight include more than 60 discharges permitted under the National Pollutant Discharge Elimination System (NPDES), from coastal industrial operations, more than 25 permitted discharges of produced water from offshore oil and gas platforms, spills, atmospheric fallout, and permitted ocean dumping of dredged material and drilling muds. The volumes of permitted discharges from coastal industries and offshore oil production platforms are small compared to wastewater discharges from municipal treatment plants. The Chevron refinery at El Segundo discharges about 6.5 million gal/day of treated brine and process water to Santa Monica Bay. Offshore oil or gas production platforms may (if permitted by NPDES) discharge up to about 0.25 million gal/day of produced water.

Inputs of various waste waters are not evenly distributed along the coast. Most of the inputs are located between Point Dume and San Mateo Point. They include approximately 82 percent of municipal wastewater effluents, 95 percent of discrete industrial wastewater discharges, 70 percent of power plant cooling water returns, and 71 percent of surface-water runoff. Oil and gas production and associated discharges occur in state and federal waters between Point Conception and Huntington Beach. Thus, there are large areas of the bight north and south of Los Angeles where discharges of waste waters to the bight are minimal.

CLASSES OF CONTAMINANTS

Oil Exploration and Production Wastes and Petroleum

Natural seeps along the coasts of Santa Barbara, Ventura, Los Angeles, and Orange counties intermittently or continuously discharge large quantities of oil and tar to nearshore waters of the bight. Fischer (1978) estimated that as few as 2,000 and as many as 30,000 metric tons (10 million gal) of oil enter the Santa Barbara Channel each year from natural seeps, the best known at Coal Oil Point. (By comparison, the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska, leaked 11 million gal of oil into marine waters.) The intertidal zone at Goleta is chronically contaminated with oil and tar from this seep. One hundred years ago, the U.S. Fish Commission steamer *Albatross* dispatched an observer to report on a huge fish kill extending from Santa Barbara to San Diego. He counted thousands of pelagic and demersal fish on the Santa Monica Bay beach at Redondo, many of them smelling of petroleum, and suggested that the event was caused by seepage from offshore "oil springs."

The first offshore oil well in the world was drilled in 1898 from a wooden pier extending into the surf zone near Summerland, California. By the mid-1980s, more than 25,000 oil and gas wells had been drilled in U.S. coastal and outer continental shelf waters. In Southern California, a large number of oil and gas fields has been discovered along the coast, both in state waters and in federal lease tracts between Point Conception and Huntington Beach (Figure 2-4). Additional fields are now being developed in federal waters north of the bight between Point Conception and San Luis Obispo. As of July 31, 1987, a total of 318 exploratory and 633 development

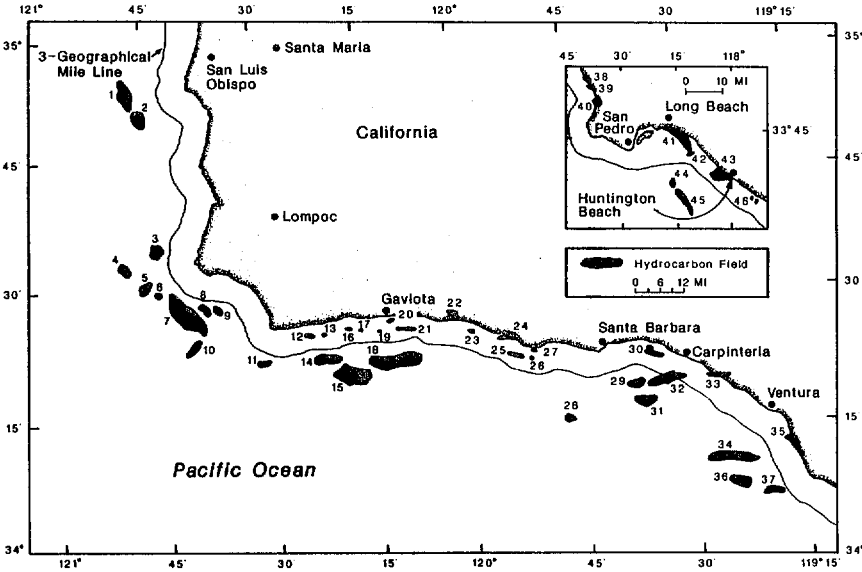

FIGURE 2-4 Major offshore oil and gas fields in state and federal waters of the Southern California Bight. Names of fields are 1, San Miguel; 2, Point Sal; 3, Point Pedernales; 4, unnamed 0443; 5, Bonito; 6, Electra; 7, Point Arguello; 8, Rocky Point; 9, Jalama; 10, Sword; 11, Government Point; 12, 13, Conception Offshore; 14, Sacate; 15, Pescado; 16, Cuarta Offshore; 17, Alegria Offshore; 18, Hondo; 19, Caliente Offshore; 20, Gaviota Offshore; 21, Moleno Offshore; 22, Capitan; 23, Naples Offshore; 24, Ellwood; 25, South Elwood Offshore; 26, 27, Coal Oil Point; 28, Santa Rosa; 29, Dos Cuadras; 30, Summerland Offshore; 31, Pitas Point; 32, Carpinteria; 33, Rincon Offshore; 34, Santa Clara; 35, West Montalvo; 36, Sockeye; 37, Hueneme; 38, Venice Beach; 39, Playa del Rey; 40, Torrance; 41, Wilmington; 42, Belmont Offshore; 43, Huntington Beach Offshore; 44, Beta Northwest; 45, Beta; 46, West Newport Offshore. SOURCE: MMS, 1987.

wells had been drilled in federal lease tracts off Southern California, most of them in the bight (Minerals Management Service [MMS], 1987).

As early as the 1920s, state fish and game wardens were frequently citing oil operations for beach spills and fish and shellfish kills. By the 1930s, these officers began reporting cooperation, cleanup, and adoption of preventive measures by the offshore oil industry to avoid oil spills. However, in large part because of the highly visible Santa Barbara Channel oil blowout of 1969, many people in Southern California consider offshore oil exploration and production to be a highly hazardous and polluting activity. In U.S. waters, spill records from offshore platforms show that of 5 billion barrels of oil produced on 41 million acres of offshore tracts leased in federal waters since 1954, 61,000 barrels were spilled (MMS, 1987), less than 0.001 percent of production.

During the 1950s and 1960s, marine life barely existed in the inner

Long Beach and Los Angeles harbors, due mainly to oxygen depletion resulting from the discharge of refinery waste waters directly into the inner harbors (Soule and Oguri, 1979; Reish et al., 1980). By the late 1960s, these inputs were reduced and partly diverted to the Los Angeles County sewage treatment plant at Carson, from which they were discharged with treated sewage off Palos Verdes. The harbors recovered, but their sediments remain heavily contaminated with petroleum hydrocarbons, metals, and other contaminants.

Today, many sources of petroleum hydrocarbon inputs to the ocean are recognized (National Research Council [NRC], 1985), and discharge of treated sewage may be a major source of aromatic and aliphatic hydrocarbons in coastal waters. Eganhouse and Kaplan (1982) estimated that the five largest municipal wastewater treatment plants in Southern California discharge a combined total of 17,400 metric tons per year of petroleum hydrocarbons to the Southern California Bight.

Dunn and Young (1976) measured elevated concentrations of the carcinogenic aromatic hydrocarbon, benzo(a)pyrene, in the mussel Mytilus edulis in Southern California. The highest concentrations occurred in mussels collected at harbor entrances. More recently, Anderson and Gossett (1986) confirmed that some Southern California harbor sediments and biota contain elevated concentrations of polycyclic aromatic hydrocarbons. Results of the National Oceanic and Atmospheric Administration's (NOAA) Mussel Watch Program reveal three locations in the bight where mussels contain elevated concentrations of total polycyclic aromatic hydrocarbons: San Diego Bay, Los Angeles Harbor, and Marina del Rey (Boehm et al., 1988). These high-molecular-weight aromatic hydrocarbons are derived from creosoted pilings, industrial (especially refinery) effluents, domestic sewage, oil spills, aerial fallout, and bilge water from ships, particularly crude oil tankers.

It is difficult, if not impossible, to construct a complete mass balance and describe long-term trends for all sources of inputs of petroleum hydrocarbons to the bight. However, inputs of petroleum hydrocarbons in treated sewage are known to have declined as the "oil and grease" fraction of the sewage declined during the last 15 years due to improved removal methods and implementation of source control and pretreatment programs. For the major treatment plants monitored by SCCWRP (1986a), oil and grease discharges decreased by approximately one-half, from 63,000 metric tons per year in 1971 to 34,300 metric tons per year in 1985.

Concentrations of total oil and grease in runoff from land and stormwater flows can be quite high. Gossett et al. (1985) estimated that the mass emission of oil and grease from the Los Angeles River was 28,600 metric tons in 1985. Some of this undoubtedly is derived from treated waste water discharged to the river by sewage treatment plants upstream.

Produced water containing up to 59 mg/liter total oil may be discharged to the ocean. If there were 25 platforms in the Southern California Bight, each discharging 0.25 million gal/day of produced water containing 50 mg/liter total oil, the amount of petroleum discharged each year from this source would amount to 450 metric tons, which is significantly less than the amount discharged from municipal wastewater outfalls in the bight. Refinery discharges have not been quantified but probably contribute a similar amount.

Radionuclides

During the 1940s, 1950s, and early 1960s, atmospheric testing of nuclear weapons by the United States, France, and the Soviet Union in the tropical Pacific, the southwest United States, and elsewhere led to the release of large amounts of radioisotopes into the atmosphere and to significant fallout of radionuclides throughout the Northern Hemisphere. There was considerable concern in California about contamination of leafy vegetable crops. Young and Folsom (1973) reported that in 1967 mussels and barnacles were contaminated with radio-manganese, cobalt, and zinc in a gradient extending from shore to far out to sea. By 1971, these radionuclides were no longer detectable in mussel tissues. Concentrations of plutonium and americium in mussels from the bight are not elevated above normal background values (Goldberg et al., 1978b). Two ocean dump sites designated in the bight for the disposal of radioactive wastes were used between 1947 and 1968. There is continued public concern about possible emissions of radionuclides to the bight from SONGS at San Clemente, and in treated sewage effluents. All discharges to the air and water from SONGS are monitored for radioactivity (Southern California Edison Company, 1987; see also Chapter 4). Sea water from the cooling-water outfall region contained natural background levels of potassium-40, but no radionuclides derived from the station. Ultratrace concentrations of cobalt-58, cobalt-60, silver-110, and cesium-137 derived from the station were detected in fish and invertebrates around the outfalls. Monitoring data from 1979 to 1985 revealed that concentrations of these radionuclides were not increasing over time in the animal tissues. The highest concentrations observed were only 1.8 percent of the levels that must be reported to the Nuclear Regulatory Commission.

Bacteria and Pathogens

Raw sewage was discharged directly into the Southern California Bight beginning before the turn of the century. However, it was not until the 1940s that public concern about the human health risks from pathogens associated with this discharge led to closure of beaches along Santa Monica Bay and in Orange County. During the late 1950s, these beaches were reopened to swimming as treatment practices improved and wastewater outfalls were diverted to deeper locations. Daily monitoring of bacteria has revealed that coliform counts at beach stations in Santa Monica Bay declined by several orders of magnitude between 1945 and 1964, and have since fluctuated around this lower level (Figure 2-5).

In spite of improvements elsewhere in the bight, significant bacterial contamination of swimming beaches persists south of San Diego. This is due to the discharge of raw sewage from Tijuana, Mexico, directly into the surf zone just south of the U.S.-Mexican border or into the Tijuana River, which empties into the bight just north of the border (Hickey, 1986). As a result, Border Field State Park and beaches as far north as Imperial Beach remain under quarantine. This problem persists despite the diversion of up to 13 million gal/day of sewage from Tijuana to the San Diego metropolitan sewer system, which occurred until 1986, when the Tijuana treatment facility came on line. San Diego now only treats emergencies (averaging less than 1 million gal/day). The total sewage flow for Tijuana has been estimated by the U.S. EPA and the International Boundary and Water Commission at between 32 and 38 million gal/day.Today, regulatory limits for coliforms in recreational waters are occasionally exceeded at some beaches following pump failures or overflows at treatment plants or flows into the stormwater drainage system due to infrequent heavy precipitation. Discharge of toilet wastes from recrea-tional vessels can be a major source of bacterial contamination in Newport Harbor and other marinas (Santa Ana Regional Water Quality Control Board, 1985). While regulatory limits have not been established for enteroviruses and other viral pathogens, the presence of such viruses in wastewater effluent and in sea water has been established (Morris et al., 1976).

Concern about pathogens in coastal waters of the bight has historically focused on beaches and the adjacent surf zone. However, increased use of offshore kelp beds by recreational and commercial divers prompted the State Water Resources Control Board to amend the California Ocean Plan to extend monitoring of surface waters for bacterial contamination to offshore kelp beds.

Thermal Discharges

The 14 coastal power plants along the U.S. and Mexican shore of the Southern California Bight generate a tremendous amount of excess heat annually. In 1972 coastal power plants generated an estimated 2 × 107 kw of excess heat (SCCWRP, 1973), and that amount is substantially higher at present. Much of this heat is discharged to the coastal zone

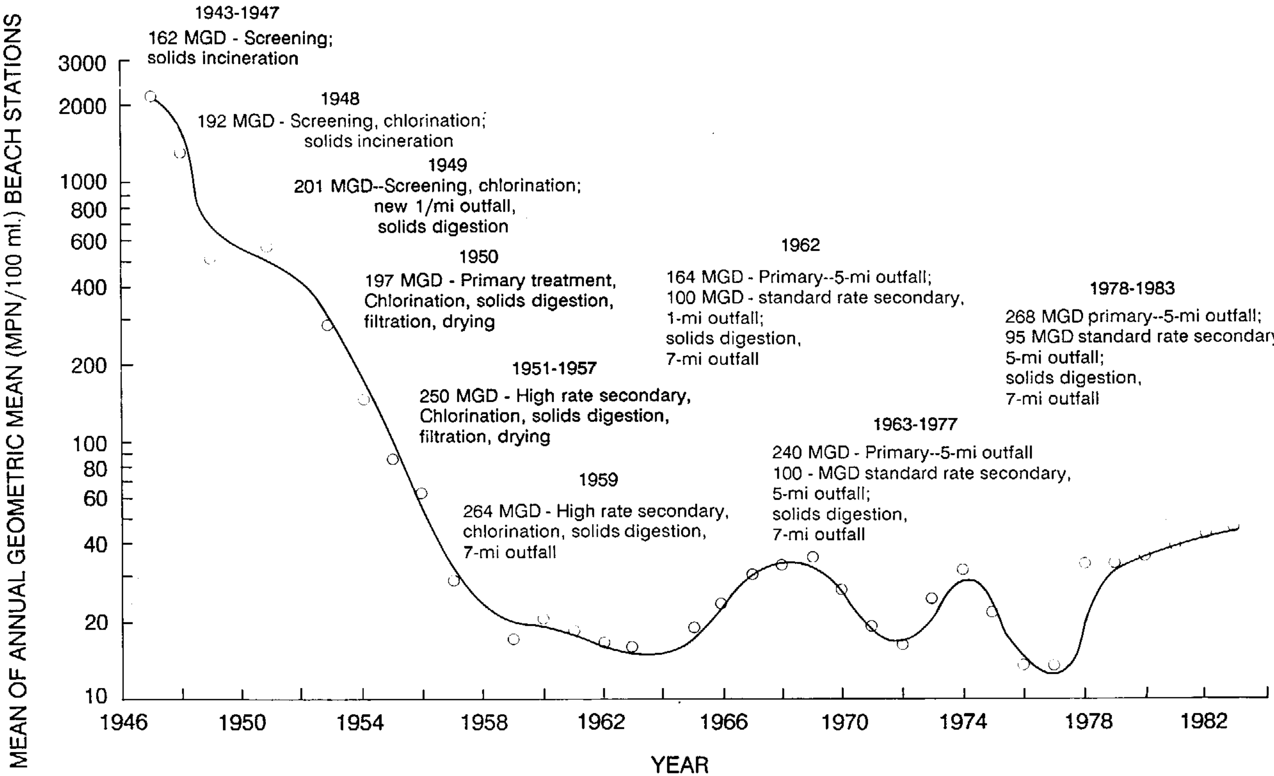

FIGURE 2-5 Counts of coliform bacteria at beach stations adjacent to the Hyperion sewage treatment plant between 1946 and 1983. SOURCE: Garber, 1987.

of the bight as waste heat in once-through cooling water. Approximately 10.7 billion gal/day of sea water is used by coastal power plants in the bight for once-through cooling water (personal communications, Southern California Edison Co., Los Angeles Department of Water and Power, San Diego Gas and Electric Company). This water may be discharged to the ocean at elevated temperatures, provided the temperature of the receiving water does not exceed 4C above ambient at 1,000 ft from the cooling-water discharge (California thermal plan [State Water Resources Control Board, 1975]). The potential effects of thermal discharge have been studied extensively and found to be either minimal or not extending beyond the immediate vicinity of the pipe (Southern California Edison Co., 1973). Traces of biocides and metals dissolved from the cooling coils are discharged (regulated by NPDES permits) with the cooling water.

Particulate Organic Matter and Solids

In lakes, estuaries, and poorly mixed marine basins, high concentrations of organic matter and inorganic nutrients from human and industrial wastes can stimulate bacterial and phytoplankton growth, leading to eutrophication and oxygen depletion. Oxygen depletion of the water can lead to severe damage to benthic and pelagic biotic communities (Rabalais et al., 1985).

The index most frequently used to indicate the tendency of a waste to cause oxygen depletion in the receiving water is the biological oxygen demand (BOD). BOD emissions to the bight have been estimated synoptically only once for all major sources—sewage, runoff, and industrial effluents (SCCWRP, 1973). However, new studies are under way. In 1971 and 1972, about 95 percent of the 297,000 metric tons of BOD discharged to the bight each year was from sewage. By 1985, BOD emissions from the seven major treatment plants had dropped to about 255,000 metric tons per year, and showed a substantial further decrease when ocean discharge of sewage sludge ceased.

It should be noted that since the early 1960s, sewage-derived BOD has been discharged directly to the ocean, not to bays, harbors, or estuaries (discharge of cannery wastes at Terminal Island ceased in 1978). Before that time, serious hypoxia in the bottom waters of Los Angeles and Long Beach harbors and San Diego Bay was nearly chronic. Since the 1960s, depressions in the concentration of dissolved oxygen in the sediments have always been minor in the open bight, even within offshore sewage discharge zones. Depressions of dissolved oxygen in the water column due to wastewater discharge have not been detected. Thus, little benefit to the dissolved oxygen resource is apparent from the substantial efforts to reduce BOD in sewage effluents. This issue merits further investigation.

The total suspended solids emissions in sewage from the seven major treatment plants have declined from 288,000 metric tons per year in 1971 to 205,000 metric tons per year in 1986, due in large part to the use of advanced primary treatment and the progressive shift to secondary treatment (SCCWRP, 1986a). These changes, along with source control, decreased chemical contaminants discharged to the bight (Figure 2-6). These improvements have not been without costs. They have resulted in increased loadings of sludge to landfills and could add to air pollution from sludge incineration in the future. Thus any regional approach to waste disposal options must ultimately consider the tradeoffs among air and water quality and land use.

A budget for suspended solids mass emissions to the bight from all sources has not been completed. Total suspended solids concentrations in stormwater flows have been monitored routinely for many years, but this information has not been synthesized and analyzed for long-term trends. In 1971 and 1972, the amount of suspended solids introduced in stormwater runoff was nearly equal to that introduced in municipal wastewater discharges (SCCWRP, 1973). The amount of suspended solids introduced in nonsewage industrial waste waters is much less than that introduced in sewage and stormwater. In the early 1980s, suspended solids discharged in waste water from five coastal refineries amounted to about 10,000 metric tons per year. By comparison, natural fluxes of suspended solids in the bight, mainly from erosion, are many-fold greater than those due directly to man's activities (Emery, 1960; Kolpack, 1987).

Dissolved Nutrients and Eutrophication

Various forms of nitrogen and total phosphorus are monitored routinely in municipal waste waters, but are rarely monitored in other effluents to the bight. The amount of ammonia nitrogen (the most useful form to phytoplankton) discharged in municipal waste water from the seven largest treatment plants, has not varied much over the years. Between 1971 and 1985, mass emission of ammonia ranged from 36,200 to 56,600 metric tons per year (SCCWRP, 1986a). Discharges of nitrate, nitrite, and organic nitrogen were much smaller and more variable. By comparison, discharges of ammonia in industrial waste water and runoff from land in 1971–1972 was estimated to be 9,500 and 440 metric tons, respectively (SCCWRP, 1973a).

Eppley (1986) compared the rate of input of ammonia and particulate organic nitrogen to the Southern California Bight in waste water to the rate at which these materials are generated by natural biological processes. The flux of ammonia and particulate organic nitrogen in municipal waste water is equivalent to the natural fluxes of these forms of nitrogen taking place under 772 mi^2 and 127 mi^2 of sea surface, respectively. Thus, it is likely

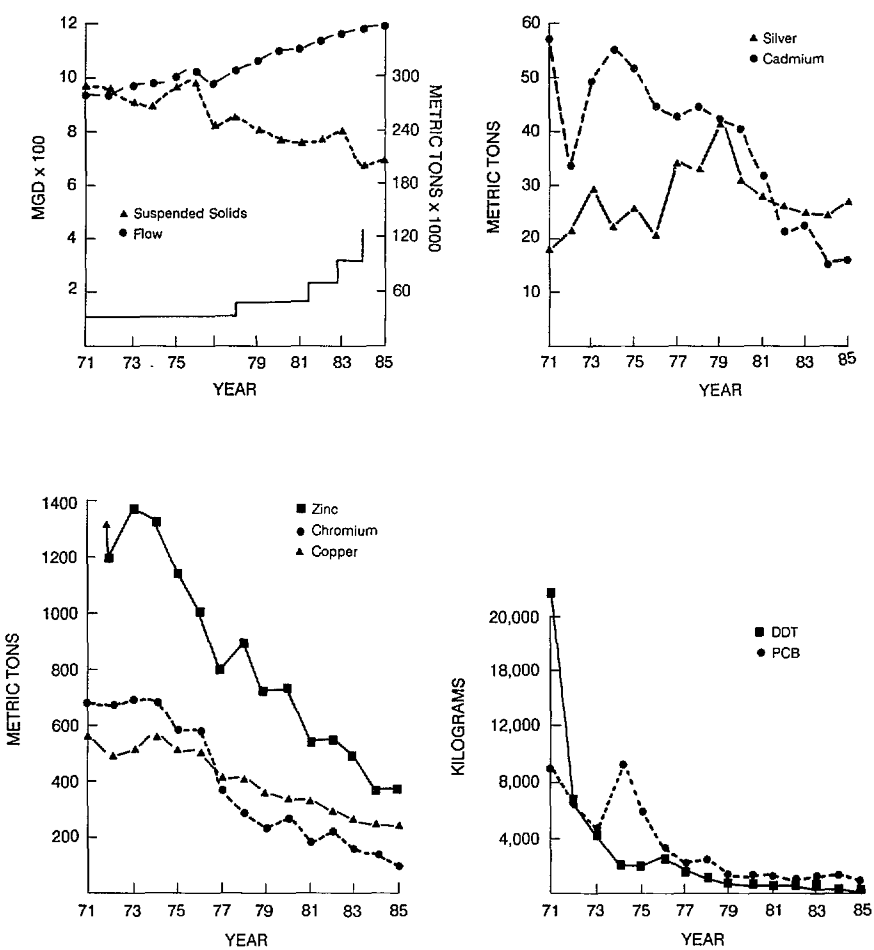

FIGURE 2-6 Mass emissions from seven large municipal sewage treatment plants discharging to the Southern California Bight, 1971 through 1985. SOURCE: SCCWRP, 1986a.

that growth of phytoplankton communities will be stimulated in the immediate vicinity of sewage and refinery outfalls if the waste water is allowed to mix into the near-surface euphotic zone. However, the likelihood of this occurring depends on the location of the outfall. For example, municipal wastewater outfalls discharge at approximately 197-ft depth, well below the thermocline. Refinery outfalls, in contrast, discharge into surface waters. Santa Monica Bay and other coastal waters of the bight have experienced several episodes of elevated ammonia concentrations and blooms of phytoplankton, possibly enhanced by wastewater discharges. Because the blooms are quite rare and wastewater discharges are continuous, it appears that factors other than these discharges play a more important role in causing blooms.

Dairy wastes, irrigation tailwaters, and urban lawn fertilizers in runoff can contribute to eutrophication in coastal estuaries and lagoons. High concentrations of nitrate in runoff water have been implicated in blooms of nuisance algae in Newport Bay (Santa Ana Regional Water Quality Control Board, 1987).

Trace Metals

There have been several attempts to estimate the fluxes of metals to the Southern California Bight from different sources. In studies performed in the 1970s, municipal waste water was found to be the major source of several metals (Table 2-2). In contrast, most of the lead entering the bight came from dry fallout from the atmosphere and stormwater runoff from land, derived primarily from combustion of leaded gasoline in automobiles. Garber (1987) found that from 1967 through 1982 the amounts of lead and mercury entering Santa Monica Bay in stormwater runoff were 40 and 52 percent, respectively, of the amounts entering the bay in municipal wastewater discharges. Garber also confirmed earlier conclusions that wastewater discharges were the major source of all other metals entering the bay. Dry or wet deposition of metal from brushfire smoke may be an additional source of metals in coastal waters (Young and Jan, 1977).

In the past 15 years, municipal sewage treatment plants have undertaken source control programs, enforced stringent pretreatment programs, and adopted procedures (including secondary treatment) that reduce the particulate emissions with which most metals are associated. As a result, the concentrations and mass emission rates of most metals have decreased dramatically in recent years (Figure 2-6). Mass emissions of several metals in sewage have decreased five- to sixfold between 1971 and 1985 (SCCWRP, 1986a). One exception is silver, for which the mass emission rate has increased from 17.7 metric tons in 1971 to 27 metric tons in 1985 (SCCWRP, 1986a).

The history of metal inputs to the bight from all sources is neatly recorded in layered sediments in its basins. They reveal that inputs increased annually through the late 1960s, then began decreasing, probably due to decreases in mass emissions of metals in sewage (Bruland et al., 1974).

Synthetic Organic Chemicals

Polychlorinated biphenyls (PCBs) and the pesticide DDT have been

TABLE 2-3 Estimated Annual Emissions (Kilograms/Year) of Selected Chlorinated Hydrocarbons to the Southern California Bight from Different Sources

Source	Year	Total DDT	Dieldrin	Total PCBs
Municipal waste water[a]	1972	6,490	100	≈ 19,460
	1973	3,920	≤ 280	3,410
	1974	1,580	95	5,290
	1975	1,270	---	3,080
	1976	940	---	2,810
	1977	770	---	1,560
Harbor/industrial	1973-74	40	10	≤ 100
Antifouling paint	1973	< 1	---	< 1
Surface runoff	1971-72	100	20	190-280
	1972-73	320	65	250-830
Aerial fallout[b]	1973-74	1,400	---	1,100
Ocean currents	1973	≤ 7,000	---	≤ 4,000

[a]Values are lower than those in SCCWRP (1986) because fewer treatment plants were considered.
[b]Includes only the inner, nearshore zone of the bight (400 x 50 km).

SOURCE: Young and Heesen, 1978; Young et al., 1981.

monitored extensively in the bight ecosystem since the early 1970s. At that time, municipal waste water was the principal source of these contaminants (Table 2-3), with additional inputs from aerial fallout and surface runoff from land (Young et al., 1976). Garber (1987) reported that between 1967 and 1982, stormwater runoff contributed 7 percent of the total identifiable chlorinated hydrocarbons contributed by municipal waste water to Santa Monica Bay. The DDT came from a local manufacturer, which discharged its wastes into the Los Angeles County sewer system from 1947 to 1971 (Chartrand et al., 1985), and other pesticides and PCBs came from a variety of sources. Analysis of dated sediment cores from the Santa Barbara Basin revealed that deposition (and therefore discharge) of PCBs to the bight began about 1945 and deposition of DDT began about 1952 (Hom et al., 1974).

Gradients of DDT and its breakdown products in coastal mussels and sediments clearly point to the Los Angeles County outfalls as the major source of DDT (Figure 2-7). Body burdens of DDT in commercial fish also are highest off the Los Angeles metropolitan area and decline steadily from Southern California to Alaska, with slight elevations in fish from San Francisco Bay and Puget Sound (Malins et al., 1987; McCain et al., 1988). Among west coast mussels sampled in the NOAA National Status and Trends Program, those from the Los Angeles area had the highest body burdens of DDT (Matta et al., 1985; Boehm et al., 1988). In 1987, mussels from San Diego Bay contained the highest mean concentrations of PCBs along the west coast (2.1 ppm). Mussels from the Los Angeles area contained a mean of 0.72 ppm PCBs (Boehm et al., 1988). Mussels in the San Diego area have contained elevated concentrations of PCBs since at least 1976 (Farrington, 1983). The source of this contamination is uncertain.

In the 1970s, manufacture and use of DDT and PCBs in the United States were banned by the Environmental Protection Agency (EPA), and since that time emissions of these highly toxic contaminants to the U.S. environment have declined dramatically. With cessation of discharges of DDT to the Los Angeles County sewage treatment plant in 1971, emissions of DDT from the seven largest municipal wastewater plants dropped dramatically, from 21.7 metric tons in 1971 to 6.6 metric tons in 1972 (SCCWRP, 1986a). Emissions of DDT continued to drop each year and were about 58 kg in 1985. Discharges of PCBs reached a peak of 9.8 metric tons in 1972 and have declined gradually to 0.82 metric tons in 1985. This decline is reflected in the sediments of the anoxic Santa Barbara Basin (Hom et al., 1974).

By 1970, the California brown pelican had been driven almost to extinction in U.S. waters from eating DDT- and PCB-contaminated anchovies (Chartrand et al., 1985). Although still on the endangered species list, the bird has made a significant comeback in the 16 years since DDT was banned (Schreiber, 1980).

Much less attention has been paid to fluxes of other synthetic organic chemicals. There is evidence that several other pesticides are important contaminants in municipal waste and storm waters. The state mussel watch program has identified several hot spots of dieldrin, chlordane, and toxaphene in shallow coastal waters and bays. The pesticides aldrin, heptachlor, and heptachlor epoxide were found in tissues of mussels from coastal regions of northern Baja California (Gutierrez-Galindo et al., 1983), but not in mussels collected by the California Mussel Watch Program along the U.S. coast of the bight (Ladd et al., 1984). A possible source of these pesticides is the Tijuana raw sewage discharge at San Antonio de Los Buenos Creek.

Priority pollutant scans of sewage of the effluent in the monitoring programs of the major municipal dischargers have revealed a wide variety of chlorinated solvents and other synthetic organic chemicals. No attempts have been made to date to estimate the fluxes of these chemicals to the bight from different sources.

Ocean Dumping

Fourteen ocean dump sites designated for disposal of a wide variety of waste materials operated for various lengths of time between 1931 and 1973 in the Southern California Bight (Figure 2-8; Chartrand et al., 1985).

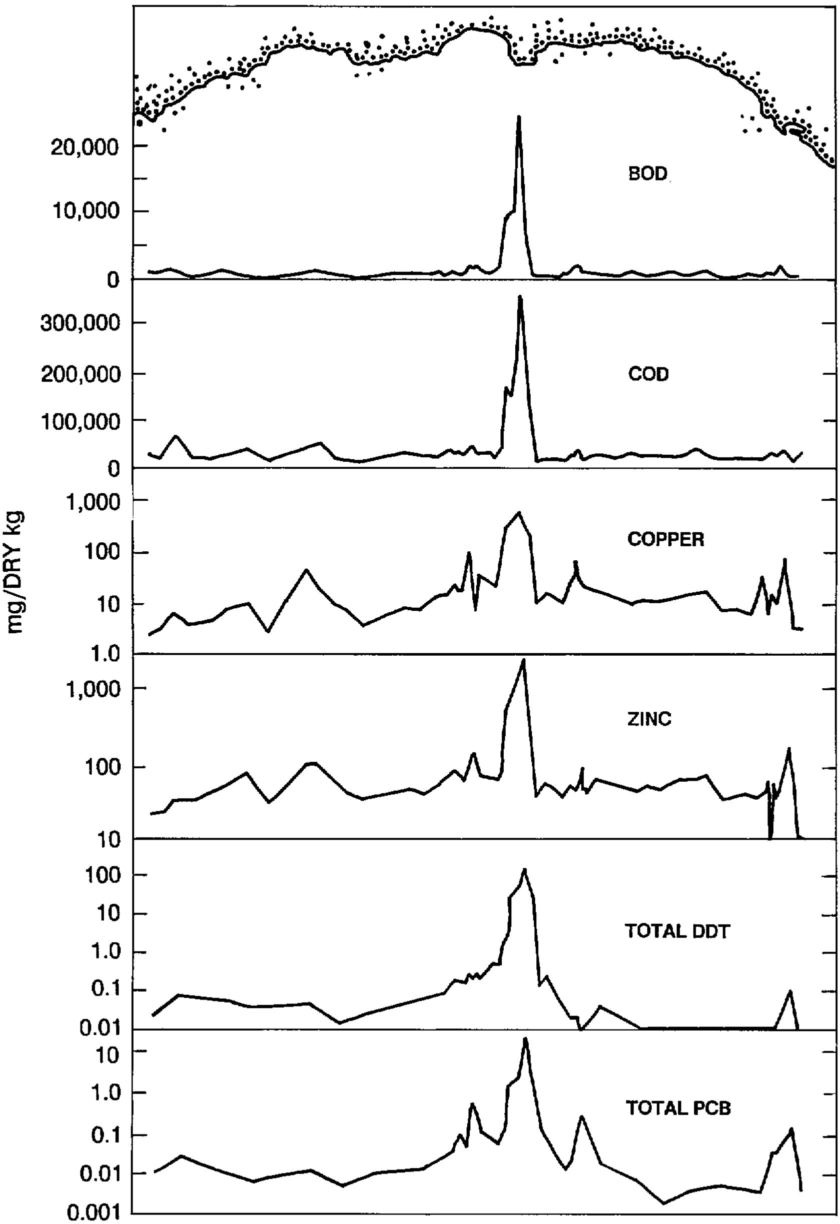

FIGURE 2-7 Variations in concentrations of six materials in surficial sediments from 77 stations along the 60-m isobath during spring and summer, 1978. The large peak is centered around the Palos Verdes discharge. Secondary peaks for some parameters are centered around the other major discharges. The major source of DDT is the Palos Verdes outfalls. SOURCE: Word and Mearns, 1979.

Between 1947 and 1961, the California Salvage Company dumped a variety of liquid industrial wastes, including approximately 2,000 to 3,000 gal/day of an acid sludge containing DDT from Montrose Chemical Company, at Dump Site No. 1 located about 10 nautical miles north of Santa Catalina Island. In 1961, the Los Angeles Regional Water Quality Control Board began regulating ocean dumping off Los Angeles County and legal ocean dumping of DDT ceased. All legal ocean dumping at this site ceased in 1973. Chartrand et al. (1985) cite instances of illegal dumping of DDT-contaminated wastes off Palos Verdes in the 1970s.

Since 1977, four open-ocean locations have been designated by the EPA for use by the U.S. Army Corps of Engineers (COE) as interim disposal sites for dredged materials (P. Cotton, U.S. EPA Region IX, personal communication; 40 CFR 228 12A). Dump site LA-1 is off Port Hueneme, LA-2 is off Los Angeles and Long Beach harbors, LA-3 is off Newport Beach, and LA-5 is off Point Loma. Approximately 2 and 3 million yd^3 of dredged material from Los Angeles and Long Beach harbors and San Diego Harbor have been dumped at the LA-2 and LA-5 dump sites, respectively. This dredged material probably was contaminated with a wide variety of chemicals, but no monitoring is being performed to determine if chemicals are being leached from it.

EPA recently designated an ocean disposal site for oil well drilling muds and drill cuttings. The site is about 16 nautical miles from Long Beach Harbor and is near the center of the San Pedro Basin. It has been used by the THUMS Long Beach Company for disposal of drilling muds and cuttings generated during drilling from four islands in Long Beach Harbor.

OVERVIEW OF ENVIRONMENTAL PROBLEMS

Contaminant input, resource exploitation, and habitat modifications due to construction and other economic activity have led to a suite of environmental problems in the Southern California Bight. Some of them are regionwide, while others are relatively localized. It is beyond the scope of this case study to present a detailed review of all environmental problems, however, awareness of their diversity is important to understanding the monitoring programs described and analyzed in Chapters 4 through 6. The following sections therefore present a brief listing of major environmental problems in the bight, and describe two of them in more detail: DDT contamination and the transport of sewage contamination from Mexico into U.S. waters.

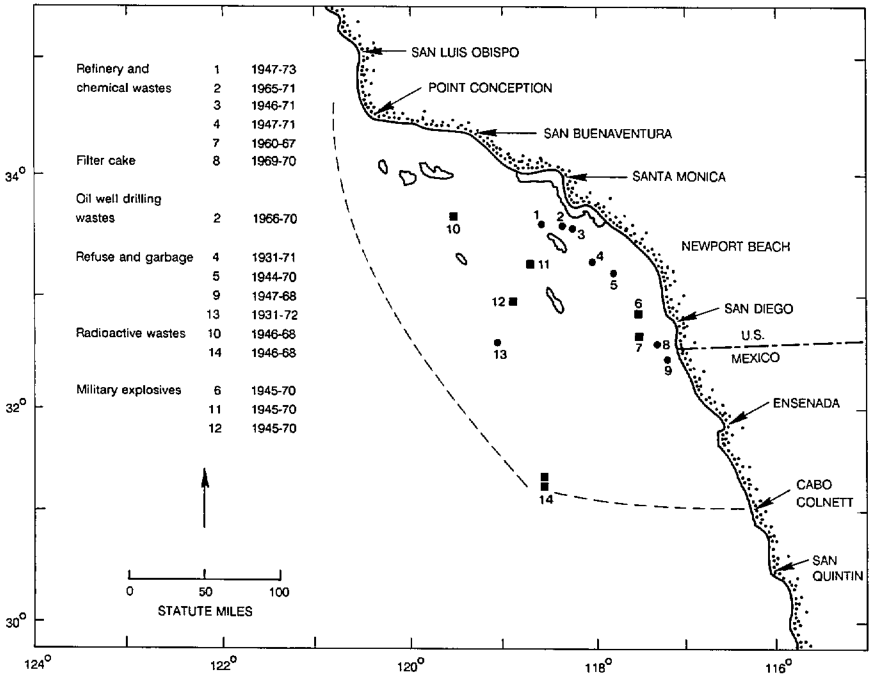

FIGURE 2-8 Ocean dump sites designated and used between 1947 and 1973. The THUMS dump site is near position 2. SOURCE: Chartrand et al., 1985.

Bightwide Environmental Issues

Many environmental problems from both human activity and natural processes in the bight extend throughout the entire bight or are extensive enough that they cross regulatory and legal boundaries. They include:

- impacts on fish and shellfish populations from commercial and sport fishing;
- impacts on fish populations from entrainment of larvae and impingement of adults by coastal power plants;
- large changes in fish populations (e.g., sardines) resulting from incompletely understood interactions between natural environmental changes and fishing activity;
- impacts on individual fish species from loss of nursery habitat due to construction and dredging;
- large changes in the areal extent of kelp beds resulting from natural environmental changes and contamination;

- regional changes in plankton populations due to nutrient enrichment by waste water;
- regional contamination of sediments and biota resulting from toxics in waste water, storm drain, and nonpoint source inflows;
- regional contamination of water resulting from pathogens in waste water, storm drain, and nonpoint source inflows; and
- cumulative effects that derive from the combination of regional and local impacts on specific resources.

DDT Contamination

One regional problem has attracted international attention. In 1967, high concentrations of DDT were reported in fish from California coastal waters (Risebrough et al., 1967). By 1970, it was known that the Montrose Chemical Company was disposing of large amounts of DDT via the Los Angeles County ocean sewage outfalls off Palos Verdes and by ocean dumping. During the next decade, numerous surveys documented the occurrence of the pesticide throughout the bight, south to Baja California, and far up coast to the north in many species of marine animals, including sea birds, seals, sea lions, and porpoises. Retrospective analyses of museum fish and dated sediment samples revealed that regionwide contamination began as early as 1950 (Chartrand et al., 1985). Until it was banned in the United States in the early 1970s, large amounts of DDT were used for agricultural and insect control. Some of the DDT reached the bight in aerial fallout, runoff from land, and municipal sewage (Young et al., 1976).

DDT continues to be used in Baja California and some of it continues to reach the bight in stormwater runoff. In recent years, large concentrations of DDT in mussels from Newport Bay have been reported (Santa Ana Regional Water Quality Control Board, 1985). These increased concentrations may be derived from agricultural soils being plowed or cleared for subdivision development and contaminating stormwater runoff. During the last decade, DDT emissions have been reduced a thousandfold (Figure 2-9) and contamination of intertidal organisms and fishes has declined (Matta et al., 1986). The widespread contamination that resulted from the combination of a large point source and many nonpoint source inputs dramatically illustrates the potential for localized problems to become regional problems over time.

U.S.-Mexico Sewage Contamination

The headwaters and mouth of the Tijuana River are in the United States, although 70 percent of its stream bed and drainage basin lie in the Mexican state of Baja California (Figure 2-10). The river has been used for disposal of raw sewage since the 1920s, and rapid population growth in the Tijuana area after World War II led to the quarantine of Imperial Beach (San Diego County) in 1959. The quarantine was lifted in 1962 after Tijuana completed its sewage system, but was reimposed in 1965 as the system failed repeatedly. As a stop-gap, an emergency pipeline was constructed to carry up to 13 million gal/day of sewage to the San Diego metropolitan system. By 1980, this pipeline was continuously at full capacity. Because of population pressures on both sides of the border, the pipeline agreement is currently being renewed on a year-to-year basis.

By the early 1980s, overflows, leakage, and failures at the Playas de Tijuana Treatment Plant and at other points in the sewer system led to multiple discharges of raw sewage (Figure 2-10)(Hickey, 1986), including the discharge of 1 million gal/day of raw sewage directly to the ocean less than 1 mile south of the Mexican border. In addition, raw sewage from some of the approximately 50 percent of Tijuana's population that is not sewered flows down open channels into the Tijuana River drainage. As a result, Border Field State Park and beaches as far north as Imperial Beach have remained under quarantine.

The regional contamination resulting from uncontrolled sewage flows from Tijuana provides a clear example of how environmental problems can cross regulatory and legal boundaries. As a result, in 1980 the San Diego County Department of Health Services, in cooperation with the San Diego Regional Water Quality Control Board and the U.S. State Department's International Boundary Commission, an agency formed by the U.S. and Mexican governments to deal with trans-border issues, implemented a monitoring program to determine the influence of Mexican sewage discharge on beaches in the border zone.

Local Environmental Problems

Many environmental problems in the bight are local; they are restricted to an area or time surrounding a specific identifiable disturbance or contamination source. Because they are easier to identify and monitor, these localized impacts are more completely understood than bightwide impacts. Localized impacts include:

- changes in benthic infauna around wastewater outfalls;
- changes in the makeup of fish communities around wastewater outfalls resulting from alterations in their food supply;
- contamination of sediments and biota in the immediate vicinity of wastewater outfalls;

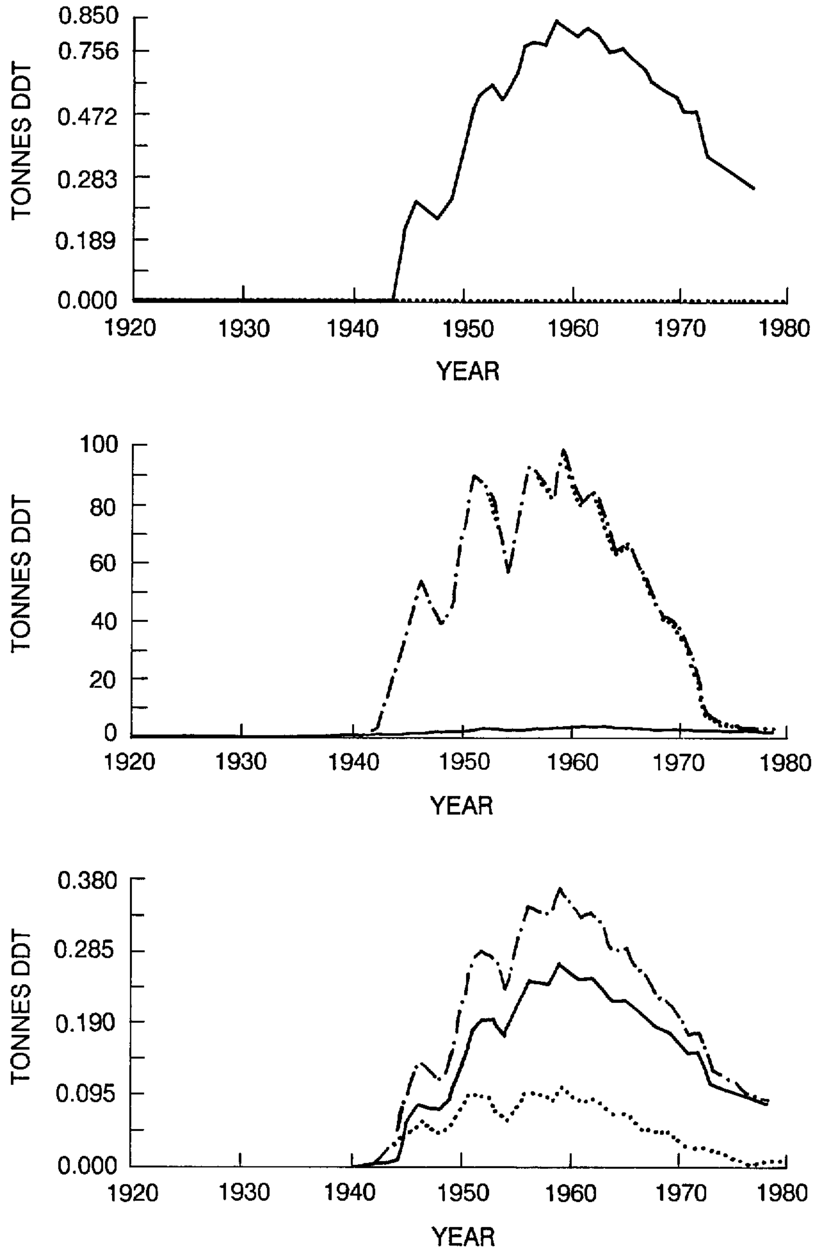

FIGURE 2-9 Total (—), nonpoint (-.-), and point source (...) estimated yearly input of DDT to the Southern California Bight from (a) Santa Barbara and Ventura counties, (b) Los Angeles, Orange, Riverside, and San Bernardino counties, and (c) San Diego County. SOURCE: Summers et al., 1987.

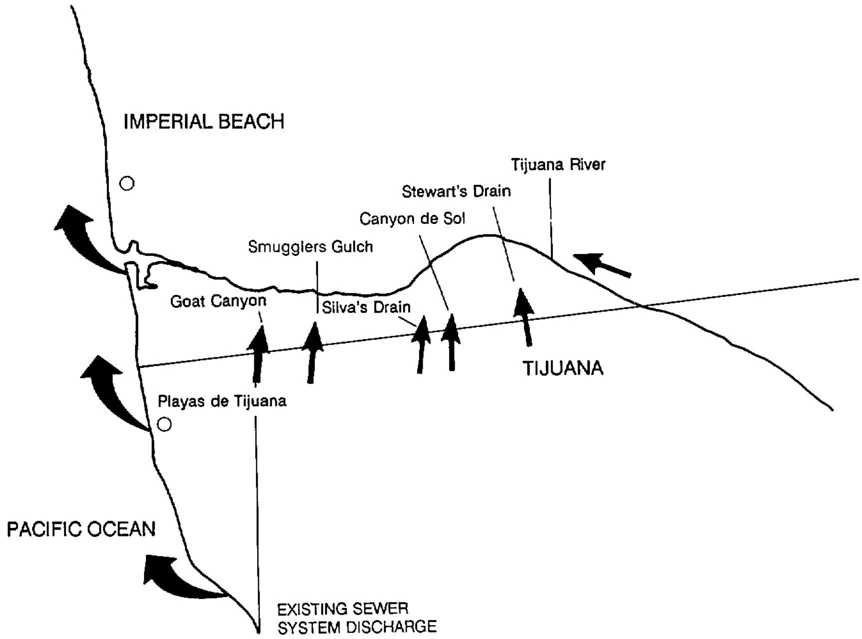

FIGURE 2-10 Locations where raw or partially treated sewage enters U.S. territory from Baja California, Mexico. SOURCE: Hickey, 1986.

- potential effects on kelp beds from the White Point and Point Loma wastewater outfalls and SONGS;
- effects on fish communities from heated power plant effluent;
- contamination of nearshore water in the immediate vicinity of storm drains;
- impacts on benthic communities from disposal of dredged material; and
- impacts on plankton populations resulting from SONGS' effects on nearshore circulation patterns.

SUMMARY

The sources of pollution in the Southern California Bight are quite varied and typical of those found in any highly urbanized coastal area of the United States, except that there are no major riverine inputs. Some of these sources are among the largest (sewage treatment plants) or most extensive (oil production) of their type found anywhere. The range of contaminants discharged is broad, and in some cases the volumes have been among the largest found in the country (for example, the historic DDT discharges through the Los Angeles County sewage treatment plant). In recent years, as a result of control strategies or changed production practices, the amounts of many contaminants discharged have declined dramatically. These reductions have resulted in decreased concentrations in the marine environment.

This great variety in sources and types of pollutants poses a formidable challenge for society as it seeks to impose appropriate controls on discharges to the marine environment. The statutory and regulatory system responsible for achieving these reductions is discussed in Chapter 3. In addition, the complexity of sources and pollutants has resulted in a set of intensive monitoring programs in the Southern California Bight, which are discussed in detail in Chapter 4.

3
Regulatory Framework and Public Concerns

As public concerns over the condition of the nation's environment grew during the 1970s and 1980s, statutes were enacted to address them. This chapter discusses the major federal, California state, and international laws that address water quality and related issues, and the agencies responsible for implementing them. Many of the decisions made by these agencies in the context of the statutory requirements are based, in part, on information derived from the monitoring system in the Southern California Bight.

Public concern over water quality has not abated, and in many ways has grown sharper in recent years. Hearings held in 1988 on the California ocean plan provided a forum for restating these concerns as they relate to monitoring and are therefore summarized in this chapter.

REGULATORY SECTOR

State and federal agencies have regulatory authority over three types of environmental issues in the Southern California Bight:

1. water quality control,
2. public health and safety, and
3. natural resources protection and management.

Marine Water Quality

The two major federal laws that regulate marine water quality are the Federal Water Pollution Control Act Amendments of 1972 and 1987 (the Clean Water Act, as amended, or CWA), and the Marine Protection, Research and Sanctuaries Act (MPRSA) of 1972. The CWA regulates all discharges into navigable waters of the United States, from fresh waters through the estuaries, the territorial sea (0 to 3 nautical miles—hereafter called the 3-mi limit), the contiguous zone (3 to 12 nautical miles), and beyond (Figure 3-1). It covers pipeline discharges to estuaries, the territorial sea, and federal waters beyond the 3-mi limit. It also covers runoff from land and dumping of wastes (primarily dredged material) from vessels into estuaries. The MPRSA regulates the transportation and dumping of wastes in marine waters from the mean low-water line of the open coast to the outer limit of federal jurisdiction. Thus, the CWA covers pipeline discharges from coastal sewage treatment plants, electric power plants, and commercial and industrial operations to fresh and marine waters, as well as discharges from oil platforms in state and federal waters. The MPRSA covers any dumping of materials from barges or ships into the ocean, including incineration of hazardous wastes at sea.

An important difference between the two laws is that the CWA is a water pollution abatement law and as such is not required to consider effects on the air and land of abatement actions for water. MPRSA on the other hand requires evaluation and assessment of all potential water, air, and land impacts before an action (e.g., dump site designation) can be taken. Thus, pipeline discharge of sewage sludge is illegal under CWA.

The primary purpose of the CWA is to restore and maintain the chemical, physical, and biological integrity of U.S. water resources (Office of Technology Assessment [OTA], 1987). This was to be accomplished by a federal grant and loan program to help municipalities to build or upgrade sewage treatment plants and by pollution control programs with regulatory requirements for industrial and municipal discharges.

The Environmental Protection Agency (EPA) is the federal agency that administers the CWA. In the state of California, the pollution control provisions of the CWA are administered by the California State Water Resources Control Board and the regional water quality control boards under authority of the Porter Cologne Act (Water Code Sections 13000 et seq.).

Section 402 of the CWA authorizes the EPA to establish and administer the National Pollutant Discharge Elimination System (NPDES) permit program. All municipal and industrial facilities discharging directly into navigable waters are required to obtain a NPDES permit. Pollution control is implemented primarily by "end of the pipe" (effluent) limitations on specific conventional chemicals that may be present in the discharge. These limitations are based primarily on considerations of current available technology (technology-based limits). Recently, there has been a growing emphasis on basing permit limitations on consideration of the quality and

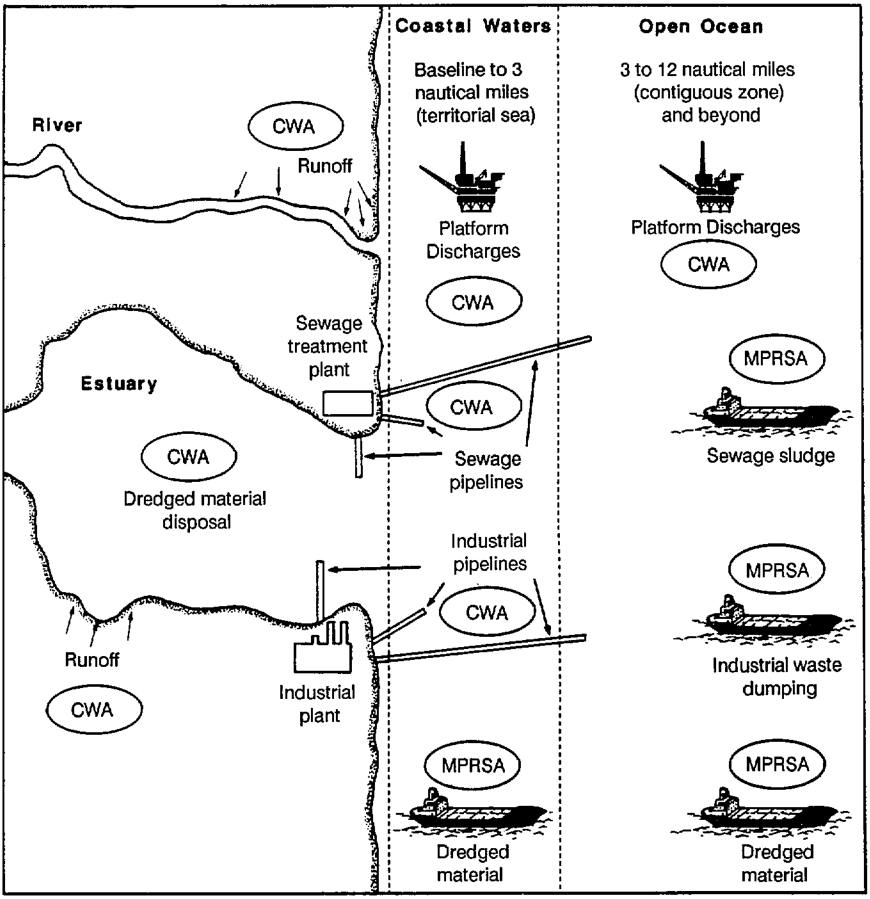

FIGURE 3.1 Jurisdictional boundaries of environmental laws affecting marine disposal. SOURCE: Office of Technology Assessment, 1987.

uses of the receiving waters (water quality-based limits). Dischargers are required to report periodically on compliance with technology-based limits. In addition, if water quality-based limits are included in the permit and the discharge is to state waters, a monitoring program is required to ensure that water quality standards and requirements are met.

EPA issues permits for discharges outside state waters (beyond the 3-mi limit) and reviews NPDES permits issued by the regional water quality control boards. EPA is also the primary permitting authority for special permits identified by the CWA, such as section 301(h), which authorizes waivers from secondary treatment of effluent discharged into marine waters if water quality objectives to protect the marine environment can be met.

In the bight, the CWA is administered through the State Water Resources Control Board by four regional boards: Central Coast (Region 3), Los Angeles (Region 4), Santa Ana (Region 8), and San Diego (Region 9). The regional boards have primary responsibility for:

- developing and adopting waste discharge requirements (limits on the discharge of wastes to state waters),
- administering monitoring programs (used to determine compliance with permit requirements), and
- developing and adopting water quality control plans (basin plans) within their respective regions.

The state board determines state policy for water quality control and reviews the basin plans developed by the regional boards to ensure that they are consistent with state policy. The state board may also adopt statewide water quality control plans or policies, which supersede the regional basin plans if there is a conflict. Statewide plans and policies dealing with estuarine, coastal, and marine waters of California are:

- the California ocean plan (Water Quality Control Plan for Ocean Waters of California [State Water Resources Control Board, 1983]),
- the California thermal plan (Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California [State Water Resources Control Board, 1975]), and
- the enclosed bays and estuaries policy (Water Quality Control Policy for the Enclosed Bays and Estuaries of California [State Water Resources Control Board, 1974]).

Statewide and regional water quality control plans designate:

- beneficial uses to be protected,
- water quality objectives (limits or levels of water quality constituents for beneficial use protection), and
- implementation of a program for achieving water quality objectives (waste discharge requirements).

The designation of beneficial uses and water quality objectives constitute water quality standards for California. Waste discharge requirements are derived from the relevant basin or statewide plan.

The California ocean plan sets the scope for most of the discharge-related marine monitoring programs in the bight. The plan has been reviewed three times (1978, 1983, and 1987) and amended twice (1978 and 1983). Additional amendments were proposed in 1988 (State Water Resources Control Board, 1988). These amendments, as well as those to the CWA in 1977, 1981, and 1987 resulted in increased monitoring requirements for dischargers.

The regulatory process and the public are linked by the regional boards, which deal with regional and local regulatory issues. Board members are local residents and the staff deals directly with local governments, agencies, and dischargers. The boards hold hearings for discharge permits, and the staff (and, when appropriate, EPA—e.g., NPDES permits for discharges into federal waters) develop ocean monitoring programs, interpret monitoring results with respect to permit compliance, and inform the public.

The MPRSA, which regulates transportation of materials to be dumped in the ocean or incinerated at sea, authorizes EPA to designate and manage ocean dumping and incineration sites. EPA also evaluates ocean dumping criteria for all permits and issues permits for ocean disposal of materials other than dredged material. The U.S. Army Corps of Engineers (COE), under Title I, Section 103, administers the permit program for disposal of dredged material at ocean sites designated by EPA. However, EPA does have the authority to review applications for dredged material disposal permits. Both agencies must determine that the proposed dumping will not unreasonably endanger human health or the marine environment according to the ocean dumping criteria, and that ocean disposal is the best environmental option.

Section 404 of the CWA regulates discharge of dredged or fill material within the 3-mi limit and in estuaries and wetlands (Figure 3-1). The COE regulates such discharges, using guidelines they developed jointly with EPA (Office of Technology Assessment, 1987). Under Section 401 of the CWA, such discharges must be certified by the affected state as complying with applicable water quality criteria. In the event of a conflict between the state and COE, or outside of COE jurisdiction, the regional boards have independent authority under the California Water Code to regulate such discharges.

Under Title I, Section 107, of the MPRSA, the U.S. Coast Guard is responsible for surveillance and enforcement to prevent unlawful dumping of prohibited material, dumping outside designated ocean dump sites, and illegal transportation of material for dumping. Title I expressly prohibits the disposal of high-level radioactive wastes and chemical and biological warfare agents. Certain other materials are allowed only under certain circumstances.

Title II requires EPA and the National Oceanic and Atmospheric Administration (NOAA) to conduct research and monitoring to assess the environmental impacts of waste disposal.

Title III of MPRSA gives NOAA the authority to establish marine sanctuaries. Inland waters and marine areas as far offshore as the edge of the continental shelf can be designated as marine sanctuaries if such designation is determined necessary to preserve or restore the area for conservation, recreational, ecological, or aesthetic purposes. The Channel

Islands National Marine Sanctuary, located in the bight, is an example. Two international conventions address ocean dumping. The first is the London Dumping Convention (LDC), which was negotiated in 1972 and became effective in 1975. It requires that all signatory nations adopt marine disposal criteria that, at a minimum, are equivalent to and contain the basic constraints of those in the LDC. The United States, Mexico, and 59 other countries have ratified the LDC. In 1974, the MPRSA was amended so that all U.S. marine disposal criteria would be consistent with and contain all the basic constraints set forth in the LDC.

The second agreement, the International Convention for the Prevention of Pollution from Ships (1973 and protocols of 1978, known as MARPOL 73/78) regulates discharges from ships. Annex 1 (covering discharges of oil) and Annex 2 (covering discharges of bulk chemicals) have been ratified by the required number of nations and are in effect. Annex 3 (covering sewage discharges), Annex 4 (covering hazardous substances in packaged form), and Annex 5 (covering garbage) await approval. The U.S. Senate recently enacted the Marine Plastic Pollution Research and Control Act of 1987 (P.L. 100-200, Title II, Sections 2001 to 2305), which includes provisions of Annex 5 of MARPOL 73/78 and prohibits ships from dumping plastics anywhere in the ocean and from discharging garbage to the ocean within 12 mi of shore, including the bight. Ports will be required to provide garbage disposal facilities for ships, and ship captains will be required to keep a waste management log, which must be available to port officials.

Public Health and Safety

State and federal agencies with primary responsibility for public health and safety within the bight's waters and along its shores are the California State Department of Health Services (DHS), the county and municipal public health agencies, and the federal Food and Drug Administration (FDA). The California Health and Safety Code and the California Administrative Code authorize the DHS to supervise sanitation, healthfulness, and safety of public beaches and public water-contact sports areas. The main focus of DHS monitoring activities is marine recreational areas from the beach out to a depth of 30 ft or 1,000 ft from shore, whichever is farther (the surf zone), and coastal kelp beds. DHS has been relying on bacteriological standards developed in 1942 (total and fecal coliforms) to judge the safety of water bodies (California Department of Public Health, 1943). When standards are exceeded, DHS or local health officials may post warning signs or declare beach closures. Permanent warning signs have been posted in the vicinity of major storm drain outlets into Santa Monica Bay and near the U.S-Mexican border. Upper Newport Bay has been closed to water-contact sports since 1974 (Santa Ana Regional Water Quality Control Board, 1985).

Under present laws and regulations, DHS can close fishing and shellfishing areas because of bacterial contamination and the presence of paralytic shellfish poisoning (PSP) organisms in marine animals. Since 1978, upper Newport Bay has been closed to shellfish gathering for human consumption because of bacterial contamination from the bay drainage area (Santa Ana Regional Water Quality Control Board, 1985). A commercial shellfish growing operation in Agua Hedionda Lagoon in San Diego County is required by its state permit to cease harvesting for seven days after rain in excess of 0.25 inches due to bacterial contamination from the lagoon watershed (California Department of Health Services, April 7, 1988). The DHS has maintained that elevated fecal coliform levels in coastal waters and in shellfish meats at a mariculture operation in the Santa Barbara Channel have resulted from the intermittent impact of undisinfected sewage effluent from both the Goleta and Santa Barbara wastewater treatment plants. In 1987, the Goleta plant initiated disinfection of its effluent prior to discharge (California Department of Health Services, 1988b, letter to Pacific Seafood Industries).

There is no specific authorization under current law to close fishing and shellfishing areas due to chemical contamination. Until recently, there was no systematic sampling of edible tissues of fisheries products from the bight to evaluate potential effects on human health from chemical contamination. However, the DHS recently issued a health advisory warning against consumption of white croaker from the Santa Monica Bay, Palos Verdes Peninsula, and Los Angeles Harbor areas because of heavy DDT and PCB contamination.

The DHS is also overseeing a year-long assessment of chemical contamination of recreational and commercial fish sampled from 25 areas in the bight. More recently, experimental quantitative risk assessment methods have been used to evaluate suspected or potential human carcinogens in fishery products. Such methods may lead to estimates of health risks from levels of contamination well below current FDA action limits.

Monitoring for coliform or other enteric bacteria is also a part of all monitoring programs administered by the regional water quality control boards and EPA around municipal wastewater outfalls. This bacterial monitoring is intended to track the wastewater plume and evaluate possible hazards to the water contact recreation shorelines.

Natural Resource Protection and Management

Several state and federal resource agencies are involved in protecting and managing the natural resources of the Southern California Bight. The

California Department of Fish and Game, the National Marine Fisheries Service (NMFS) of NOAA, and the Fish and Wildlife Service (FWS) of the U.S. Department of the Interior (DOI) are all involved in protecting and managing living marine resources. Their activities include fish stock assessments and habitat protection. The State Lands Commission is responsible for leasing tidal and submerged lands out to the 3-mi limit for energy and mineral development, subject to the Public Trust Doctrine. The California Department of Fish and Game and the Department of Health Services issue permits for commercial shellfish growing, subject to review by the State Lands Commission. The DOI's Minerals Management Service (MMS) is responsible under the Outer Continental Shelf Lands Act of 1953 (OCSLA) for leasing energy and mineral rights in federal waters extending from the 3-mi limit to the outer limit (200 mi) of the Exclusive Economic Zone (EEZ).

Resource exploitation, management, and protection activities must comply with several federal regulations in addition to those dealing with water quality. The National Environmental Policy Act of 1970 (NEPA) requires that an environmental impact statement (EIS) be prepared for all proposed legislation and all major federal actions that could significantly affect the quality of the environment. Thus, the MMS prepares an EIS before leasing offshore tracts for oil and gas exploration. Although EPA is not required to prepare an EIS for ocean disposal site designations, its policy is to do so voluntarily for dump site and incineration site designations. EPA also prepared an EIS in 1977 when it proposed revisions to the ocean dumping regulations and criteria.

The Endangered Species Act of 1973 requires all federal and state agencies to ensure that any action they authorize, fund, or carry out will not jeopardize the existence of an endangered or threatened species or result in damage or destruction of critical habitat for such species. The act authorizes the NMFS and FWS to render a biological opinion about the potential effect of a proposed activity on endangered species. As part of the EIS process, one of these agencies, usually upon consultation with the California Department of Fish and Game, must attest that the proposed action is compatible with the Endangered Species Act.

The NMFS and FWS are empowered by the Marine Mammal Protection Act of 1972 to enforce a moratorium on the taking or importation of marine mammals and marine mammal products except by special permit from the Secretary of Commerce. The National Historic Preservation Act protects historic and prehistoric archaeological resources.

The Coastal Zone Management Act of 1972 (CZMA) administered by NOAA provides grants to coastal states to develop coastal management plans. It also provides for state review of federal actions, including leasing of tracts for oil development and designation of ocean dump sites in federal waters that might directly affect the coastal zone. Although the State Water Resources Control Board has primary authority to regulate water quality, the California Coastal Commission is responsible for reviewing federal actions for consistency with the state's coastal management plan. In this role, the commission has had a major influence on proposed oil and gas development activities on California's outer continental shelf.

Under the CZMA National Estuarine Reserve Research Program, the Secretary of Commerce may designate a state or estuary as a national reserve upon nomination for such designation by the state's governor. The Tijuana Estuary is the first estuary in the Southern California Bight to receive such status.

The California Coastal Commission controls development within the coastal zone by issuing permits and approving local development plans in accordance with the California Coastal Act of 1976. The California Coastal Conservancy is authorized to make grants to local governments to acquire and restore critical habitats, including coastal wetlands.

INTERAGENCY COOPERATION

Complex environmental problems may not fall neatly within the areas of responsibility of individual agencies. They may involve the responsibilities of several agencies, or none, and may cross jurisdictional boundaries. In delegating responsibility for regulatory activities in the bight to different state and federal agencies, the U.S. Congress and the state legislature have not always been able to anticipate such problems. As a result, agencies must deal with policy conflicts, gaps, and overlaps. In addition, monitoring and research results generated by one agency can relate to the statutory responsibility of another. There are several examples in the bight of interagency cooperation that has successfully resolved such conflicts, and a few are mentioned below.

The previous chapter described how the San Diego County Department of Public Health, the San Diego Regional Water Quality Control Board, and the U.S. State Department's International Boundary Commission cooperated on the design of a monitoring program to assess sewage contamination from Tijuana. In addition, the EPA's Region IX office cooperates with the U.S. Army COE and with the Regional Water Quality Control Boards in establishing discharge and disposal limitations and monitoring programs.

The California Cooperative Oceanic Fisheries Investigation (CalCOFI) program is a long-standing example of a joint monitoring and research program involving federal and state resource agencies and an academic institution. The State Water Resources Control Board and the California Department of Fish and Game have combined resources to establish a statewide Mussel Watch Program to monitor toxic contamination. This program complements NOAA's National Status and Trends Program. The NOAA Sea Grant programs (which receive matching funds from the state of California), the U.S. FWS, the Coastal Conservancy, and the California Department of Fish and Game have cooperated in coastal wetland restoration projects.

Responding to mounting public concern over the condition of Santa Monica Bay, the Southern California Association of Governments (SCAG), funded the Santa Monica Bay Study. The study's goal was to compile all data relevant to the bay, perform an overall assessment of the state of its marine environment, and develop an implementation plan for specific actions to improve it. The study's steering committee is a consortium of representatives from local and state governments, environmental and academic groups, federal agencies, and local dischargers. Ten local entities and the SWRCB (using Clean Water Act monies) are funding the study. The San Diego Regional Water Quality Control Board has initiated a similar program to address environmental problems in San Diego Bay.

PUBLIC CONCERNS FOR THE BIGHT

There is intense public interest and awareness about environmental quality in Southern California. As a result, the public has been very vocal in advocating strong and effective environmental protection policies for the Southern California Bight. A sampling of public concerns and perceived policy needs for the bight ecosystem can be gained from the October 1986 triennnial review of the California ocean plan (State Water Resources Control Board, 1987) and from the presentations of interested parties to the case study panel. The following points were made by representatives of citizen organizations:

- The California ocean plan (State Water Resources Control Board, 1987) needs clearer definitions of narrative terms such as "degrade." It is difficult to assess the information provided by monitoring in the context of such vague objectives.
- Not enough attention is being paid to nonpoint sources of contaminants entering the bight, such as stormwater drains and aerial fallout. The plan should consider placing monitoring requirements on these sources.
- There should be a shift from discharge standards and effluent limitations based on allowable concentrations of contaminants in receiving waters to standards and limitations based on mass emissions of contaminants. This would better reflect the loading of the marine environment.
- A more complete assessment of the cumulative effects of marine contamination is necessary.

- The plan should require monitoring of sediments and biota to better assess cumulative levels of contaminants and their associated effects.
- There should be more independent review and oversight of the monitoring programs performed by dischargers.
- Self monitoring should be eliminated and monitoring put in the hands of state agencies.
- There should be better analysis of monitoring data submitted to public agencies and better communication of that information to the public.
- An oceanic institute associated with local universities should be established to conduct regular monitoring currently performed by dischargers, to coordinate monitoring by other agencies, and to perform related research.
- Standardized bioassay protocols and bioaccumulation tests should be required to better assess the toxicity of effluents to marine life and the hazards of eating fishery products from coastal areas.

The public appears to expect monitoring activities to provide information that answers four basic questions:

1. Is it safe to swim in the ocean?
2. Is it safe to eat the local seafood?
3. Are fisheries and other living resources being adequately protected?
4. Is the health of the ecosystem being safeguarded?

These are the public expectations that the panel perceives drive the actual monitoring programs. However, monitoring is carried out within a broader societal context, which includes such issues as cost, the effects of competing uses on land, water, and air quality, and tradeoffs between short and long-term costs and benefits. The challenge is valid and useful to management decision making in that it provides information addressing public concerns.

SUMMARY

The regulatory framework in the Southern California Bight is indeed complex and far reaching. Successful implementation of monitoring programs often requires a high degree of cooperation among state and federal officials. The efficient design of a monitoring system that can meet the various objectives of regulatory interests and not impose unreasonable burdens on the regulated community is a formidable task. In succeeding chapters, the details of this system are discussed and its success at meeting these criteria assessed.

In part, the success of the regulatory program and the role that monitoring plays depend on public confidence. The public continues to question the efficacy of monitoring and the status of the marine environment. Subsequent chapters will offer suggestions about the technical design of monitoring programs that may address those questions.

4
Monitoring and Research in The Southern California Bight

The relationship between research and monitoring activities in the Southern California Bight is complex, making it difficult to arbitrarily and consistently distinguish between the two. In this report, monitoring generally refers to repeated measurements taken to comply with specific regulations: research refers to measurement and experimental programs undertaken to answer more open ended questions. In the panel's view, monitoring and research are complementary activities that support each other and that both provide important information needed for resource management. Often the same agency will fund and/or direct both monitoring and research. Monitoring results have stimulated research programs, and research results have provided information that has been helpful in reducing impacts and refining monitoring requirements. In addition, research activities are often an integral part of monitoring programs in the bight.

Although this chapter reviews research and monitoring programs separately, it is important to remember the significant links and interactions between the two activities. These links exist because both monitoring and research are concerned with measuring and understanding processes of marine environmental change.

In general, monitoring in the bight is focused on four broad areas of concern:

1. the effects of effluent from municipal sewage treatment plants;
2. the effects of effluent from other sources, such as power plants, refineries, and nonpoint sources;

3. the status of resources such as fisheries and kelp beds; and
4. effects on public health from water contact sports.

Although these are useful organizing principles, in reality specific programs overlap the boundaries between them. Monitoring related to each of these four concerns is complemented by active research programs.

The main characteristic of research and monitoring activities in the bight is their broad diversity. Federal, state, and local agencies, along with universities and private industry, are active members of the research and monitoring community. This diversity stimulates innovation and careful evaluation of research and monitoring results, but it also makes coordination and integration of monitoring more difficult.

THE MONITORING SECTOR

The four monitoring areas described above reflect the existing regulatory environment (Chapter 3), with each kind of monitoring responding to a different set of laws, regulations, permits, and limitations. (A comprehensive review of past and present monitoring programs can be found in SCCWRP, 1988.) Effluent discharge and monitoring are controlled by National Pollutant Discharge Elimination System (NPDES) permits, which can contain effluent limitations (pertaining to the effluent) and water quality objectives (pertaining to the receiving waters). In California, these are determined by EPA, based on provisions of the Clean Water Act, as amended (CWA), and by the regional water quality control board issuing the permit, based on the California ocean and thermal plans (State Water Resources Control Board, 1975, 1987). Effluent limitations are specific numerical standards; water quality objectives include both numerical (Table B of the California ocean plan) and narrative standards (such as degradation of the environment).

The numerical effluent limitations are a combination of federal and California ocean plan (State Water Resources Control Board, 1987) regulatory requirements and are based primarily on consideration of current available technology (the technically or financially most feasible level of contaminant removal attainable). Effluent limitations may be stated as maximum acceptable concentrations of a constituent in the effluent or as the maximum allowable mass emission per day. For thermal effluents, for example, the maximum allowable difference in temperature between the effluent plume and the receiving waters at 1,000 ft from the outfall or diffuser is 4°C (California thermal plan [State Water Resources Control Board, 1975]). Compliance with such effluent limitations is determined directly by analysis of effluent at specified intervals.

The water quality objectives are also determined according to federal laws and regulations and California ocean plan requirements (State Water

Resources Control Board, 1987). They are numeric or narrative expressions of the maximum allowable changes in various environmental parameters that will not result in serious or long-term damage to the affected marine ecosystem. Numeric objectives define allowable concentrations of waste constituents after allowing for mixing within the zone of initial dilution (ZID), the region within a specified horizontal distance from the end of an outfall or any point along a discharge diffuser. The horizontal distance is usually equal to the water depth at the discharge. In contrast to establishing numeric objectives, demonstrating compliance with the narrative water quality objectives can be difficult. It is based on periodic monitoring of environmental conditions in the vicinity of the effluent discharge, and criteria used to measure compliance with these narrative objectives are often subjective and inferential.

In contrast to this system of effluent monitoring, resource monitoring is structured around compilation of commercial and sport catch statistics and studies of the status of particular stocks.

Routine health effects monitoring measures concentrations of bacterial indicators (e.g., coliforms) along beaches to determine whether to close sections of the coast to body contact sports.

The following sections describe monitoring activities related to the major sources of effluent and habitat change in the bight.

Municipal Discharges

There are 16 municipal wastewater dischargers operating under NPDES permits in the bight (Table 4-1). Of these, only the discharges in Goleta, Orange County, and Encina have received waivers under Section 301(h) of the Clean Water Act, as amended. Encina voluntarily relinquished its waiver in 1988. The largest of the 16 discharges are operated by the city of Los Angeles (Hyperion), the County Sanitation Districts of Los Angeles County (White Point), the County Sanitation Districts of Orange County, and the city of San Diego (Point Loma) (Southern California Coastal Water Research Project [SCCWRP], 1987). (Detailed histories of the regulatory actions and monitoring programs at each of these four large discharges can be found in SCCWRP, 1988.) In general, monitoring evolved from measurements of fecal contamination in the nearshore zone to more comprehensive assessments of environmental conditions over a broader area.

Table 4-1 summarizes the required monitoring programs at each municipal discharge in the bight. The wide variety in monitoring requirements among these discharges reflects differences in the size of each discharge, the levels of contaminants present, and the nature of the nearby marine environment (e.g., presence of kelp beds or other valued resources). In addition, permits were granted at different times, and their requirements reflect improvements in knowledge about the environment and changes in regulatory emphasis. Differences among monitoring programs also stem from the diverse orientations of the four regional water quality control boards that administer NPDES permits in the bight. These are the Central Coast, Los Angeles, Santa Ana, and San Diego regional boards. Boards differ in their staffing, level of experience, and responsiveness to local issues. As described in Chapter 3, the regional boards are relatively autonomous.

The current monitoring programs at two large municipal discharges, along with their historical contexts and existing permit conditions, are described in detail below. This will illustrate how monitoring has developed, as well as the relationship among regulatory requirements, public concerns, monitoring programs, and management decisions based on monitoring data.

County Sanitation Districts of Orange County

The County Sanitation Districts of Orange County (CSDOC) currently provide service to more than 2 million people in 23 of the county's 26 cities (CSDOC, 1987; SCCWRP, 1988). Two treatment plants, one at Fountain Valley and the other at Huntington Beach, process about 255 million gal/day of waste water. About 80 percent of the flow is from residential and commercial users, and 20 percent from industry. The effluent, consisting of about 40 percent primary treated and 60 percent secondary treated waste water, is discharged through an outfall 5 mi from shore in 200 ft of water off Huntington Beach.

The discharge at Orange County was initiated in the 1920s with screened effluent disposed of a short distance into the surf near the mouth of the Santa Ana River. In 1949, bacterial monitoring along the beach within 5 mi of the discharge was instituted at the request of the state health department. In the mid 1950s, expanded treatment facilities and a new outfall that discharged approximately 1 mi offshore were constructed. As a consequence, the monitoring program was expanded in 1960 to include offshore sampling of both the water column and sediments. In the late 1960s, sampling at additional nearshore stations was begun, and bacterial monitoring at shoreline stations was increased to 5 days per week.

In 1971, effluent was diverted from the old outfall 1 mi from shore to a new outfall 5 mi from shore. At this time, the Santa Ana Regional Water Quality Control Board designed a monitoring program to study the effects of the change. Additional parameters and stations were added to the existing monitoring program. The following year, monitoring of fish populations began with the addition of trawl sampling to the program.

The 1974 NPDES permit for the discharge increased the nearshore bacterial monitoring effort and required additional stations and parameters

TABLE 4-1 Monitoring programs of the 16 Municipal Wastewater Dischargers in the Southern California Bight

	Flow MGD	Bact-eria	Water Column	Sediments/ Infauna	Epifauna/ Fish	Tissue Analysis	Histopa-thology	Mussel Cages	Kelp
Goleta (301h)	6.8	*1/week; 7 sta*	8 sta/ month	6 sta; 3 reps(ea); semiannually	2 sta annually	3 compo-sites at 2 sta	no	no	no
Santa Barbara	11	*1/week; 5 sta	4 sta quarterly	8 sta semi-annually every 3rd year	fish, 5 sta semi-annually every 3rd year		no	no	no
Montecito	1.5	No	No	4 sta; odd years					
Summerland	0.15	No receiving water monitoring							
Oxnard	22.6	*1/week; 21 sta	7 sta quarterly	3 reps (ea); 7 sta semi-annually	3 sta semi-annually; 2 reps	2 sta; 3 reps; 1 spp annually	no	no	no
Los Angeles City, Hyperion	400	7sta/day plus 17 11 sta/ week	25 sta/ week	3 reps; 39 sta/ quarterly	6 sta quarterly	6 sta annually; 3 sta semiannually	no	no	no
County Sani-tation Districts of Los Angeles County, JWPCP	360	7days/ week; 7 sta; 1/week; 5 sta	118 month	18 sta semiannually; 44 stations every 5 years	8-12 sta semiannually	12 sta quarterly			Diving 8 sta semi-annually
Los Angeles City, Terminal Island	20	1day/week; 3 sta	7 sta/ month	no	no	no	no	no	no

Avalon	0.4	1day/week; 5 sta; 1day/month	5/week	5 rep cores; 5 stations annually	no	no	no	no	no
County Sanitation Districts of Orange County (301h)	255	5days/ week; 17 sta	9/month 17/quarter	3 or 5 reps; 13 sta/quarter + 40 annually	2 rep trawls at 8 sta semiannually	12 sta semi-annually	60 fish per year	yes	no
Aliso (ALMA)	12	2days/ week; 16 sta	7 sta/ month	7 sed/year 5 rep/7 sta/year 1 rep/7 sta/year	no	no	no	no	annual aerial photo
SERRA	13.5	1/month; 31 sta	7 sta month	7 sta annually	no	no	no	no	no
Oceanside	11	1/month; 21 sta	7 sta annually	No additional monitoring if effluent meets standards					
Encina (301h, 85-88)	15	*1/week; 5 sta	11 sta/ month	6 sta annually; 5 reps	no	4 sta semi-annually	2 sta 3 composites annually	no	annual aerial photo
San Elijo	16.7	1/month; 2 sta	7 sta/ month	7 sta/sed 6 months metals & phenols; 7 sta/year biota 3 sta/year	no	no	no	no	qtrly aerial photo
San Diego City, Pt. Loma	180	*2days/week; 8 sta; 20 sta; month	20 sta/ month	18 sta/quarter; infauna-5 reps	no	no	no	no	annual aerial photo

*= sampling is more frequent in summer than in winter.
ª sta=stations; reps=repetitions
SOURCE: Collected for the committee by SCCWRP.

in the offshore monitoring program. In particular, metals, phenols, biological oxygen demand (BOD), pesticides, and PCBs were to be measured in offshore sediments. In the late 1970s, this program was amended to reduce sampling for benthic biota to twice yearly instead of quarterly.

In 1978, the districts began operating an activated sludge facility at the first of their two treatment plants, and in 1983 at the second. These facilities improved the quality of the wastewater discharge.

In 1985, the Environmental Protection Agency (EPA) granted the CSDOC a 301(h) variance for a five-year waiver from the complete secondary treatment requirements of the CWA. An expanded monitoring program was required as a condition of the NPDES permit issued jointly by the Santa Ana Regional Water Quality Control Board and EPA Region IX (Table 4-2). EPA will use the monitoring data to assess whether the 301(h) permit should be renewed upon expiration, while the regional board will use them to determine compliance with the 1983 California ocean plan (State Water Resources Control Board, 1983). EPA must conduct a public hearing to consider any major changes to the permit conditions. If there is major opposition to such changes, they may not be allowed. Regional board action is also required for any substantive modification of the permit conditions.

As described above, the NPDES permit contains effluent limitations and water quality objectives. It also contains specific provisions and time tables for meeting the limitations of the permit and submitting various reports. The overall objectives of this 301(h) monitoring program, as specified by EPA (1987) and 40 CFR 125.62, are to:

- determine compliance with NPDES permit terms and conditions;
- document short- and long-term effects of the discharge on receiving waters, sediment, biota, and on beneficial uses of the receiving water; and
- assess the effectiveness of toxics control programs that limit discharge of toxic chemicals to the receiving waters.

To accomplish these objectives, the permit (No. CA0110604) specifies several kinds of monitoring (Table 4-2) and their objectives (Table 4-3).

City of Los Angeles

The city of Los Angeles' Hyperion treatment plant in Playa del Rey, with a design capacity of 420 million gal/day, is the largest sewage treatment plant discharging treated waste water to the bight (SCCWRP, 1988; John Dorsey, Hyperion Treatment Plant, personal communication). Planning is currently under way to double its capacity. The flow averages approximately 75 percent primary treated and 25 percent secondary treated waste water.

Treated wastes are discharged to Santa Monica Bay through an outfall

TABLE 4-2 Summary of the 301(h) Water Quality Monitoring Program Performed by the County Sanitation Districts of Orange County

Program element	Number of stations and frequency	Replicates/ station	Parameters measured
Beach coliforms	17 daily	1	Total coliforms (MPN/100 ml)
Water quality	9 monthly; 17 quarterly	1 each every 3 (or 6) m to bottom	Temperature, salinity, light transmission, total suspended solids, ammonia, coliforms, water color, dissolved oxygen, pH
Trawls (demersal communities)	8 semiannually	2	Fish/epifauna taxonomy, health, length/weight of 30 species
Benthic grabs	13 quarterly; 40 annually	Quarterly—infauna, 3 chemistry; annually—1 infauna, 1 chemistry	Infauna retained on 1 mm screen, grain size, oil, cyanide, sulfide, volatile solids, metals, extractable organics, pesticides, PCBs, volatile organics, total organic carbon
Bioaccumulation			
infauna	6 annually	5 g tissue total	Metals, synthetic organics, pesticides
fish	5 annually	20≈60 specimens	Metals, synthetic organics, pesticides
epifauna	5 annually	5≈58 specimens	Metals, synthetic organics, pesticides
Fish histopathology	8 semiannually	60 specimens	Liver histopathology, visual for tumors and lesions
Sport fishing survey	4 semiannually	As many as possible	Metals, synthetic organics, pesticides; liver histopathology, visual for tumors and lesions

terminating about 5 mi from shore in about 187 ft of water. Until November 1987, digested sludge and secondary effluent in a ratio of 1 to 3 were discharged through an outfall terminating nearly 7 mi offshore at the head of Santa Monica submarine canyon in about 300 ft of water. Periodically, during unusually high flows or in emergencies, chlorinated secondary effluent may be discharged through an outfall that terminates 1 mi from shore in 50 ft of water.

The city of Los Angeles began discharging raw sewage into Santa Monica Bay at Hyperion in 1894, and constructed a central outfall sewer in 1908. At the time, the area was relatively remote and there was minimal awareness about potential health hazards associated with the discharge of raw sewage. The State Department of Health began receiving complaints about fouled beaches in the vicinity of the discharge by 1912. As a result, an outfall was constructed in 1924 to carry screened effluent 1 mi offshore. However, a break in the outfall pipe 500 ft from shore, a growing urban population, and the need to bypass the screen during storm flows led to

TABLE 4-3 Objectives Specified in the NPDES Permit for the 301(h) Monitoring Program Performed by the County Sanitation Districts of Orange County.

Program element	Objectives
Beach and surf zone	Assess bacteriological conditions in areas used for water contact sports and shellfish harvest. Determine effectiveness of treatment to remove floatables that affect health and aesthetics.
Water column	Determine compliance with water quality objectives. Provide data to support interpretation of biology data.
Trawls (demersal communities)	Assess presence of balanced indigenous populations of demersal fish and benthic invertebrates.
Benthic grabs	Assess presence of balanced indigenous population of benthic invertebrates. Evaluate physical and chemical quality of the sediments.
Bioaccumulation (mussels, infauna, fish, epifauna)	Determine accumulation of toxic pollutants.
Fish histopathology	Assess prevalence of lesions, tumors, and liver abnormalities in local fish.
Sport fishing survey	Monitor uptake of pollutants in fish consumed by humans in order to determine impact on public health. Assess impacts on local fish populations.

repeated recontamination of Santa Monica Bay beaches. This caused the Department of Public Health to close beaches near Hyperion in Santa Monica Bay from 1946 to 1951 due to bacterial and grease contamination.

These continued problems with bacterial and aesthetic contamination led to legal action that resulted in construction of a larger outfall and a secondary treatment system in 1950 (Garber and Wada, 1988). Treated effluent and about 50 percent of the sludge were discharged to the bay, and reduced levels of contamination allowed the beaches to be reopened in 1951.

By 1952, growing public concern about contamination of Santa Monica Bay prompted comprehensive investigations by the Scripps Institution of Oceanography and the University of Southern California's (USC) Allan Hancock Foundation. The studies' objectives were to determine the bay's physical and biological conditions, sources and magnitude of pollution, and optimal design and location for deep-water outfalls. Based on data showing that bacterial contamination never traveled more than 5 mi along the beach in either direction from the outfall, a 5 mi-long effluent outfall was built in 1959. Prior to that, a 7 mi-long outfall had been built in 1957 to carry sludge to the head of Santa Monica Canyon.

Monitoring began coincident with the closure of public beaches in 1946, when routine daily surf and water column monitoring for coliforms was initiated by the Department of Public Health. This program was later incorporated into the monitoring mandated by the Regional Water Quality Control Board, and in 1956 was expanded to include additional water column and shoreline stations throughout the bay. This was the first such marine monitoring program in Southern California.

Hyperion's monitoring program was significantly enlarged in 1974, with the issuance of the plant's NPDES permit by the EPA and the state and regional water quality control boards. This permit required monitoring of infauna, some sediment chemistry, and water column bacteria. In 1980, the city signed a consent decree to cease sludge discharge to the ocean by February 15, 1986 (later extended to December 31, 1987). In 1982, the city of Los Angeles applied for a 301(h) waiver from the requirements to convert to secondary treatment, which EPA initially approved. The Los Angeles Regional Water Quality Control Board did not concur, and a waiver was not issued. However, in 1984 monitoring requirements under the existing NPDES permit were increased with the addition of trawling and replication at several benthic stations both within and outside the ZID of the 5-mi outfall. Hyperion received a new NPDES permit in 1987 that included a greatly expanded and modified monitoring program (Table 4-4).

The overall objectives of the Hyperion monitoring program differ somewhat from those of the Orange County program, partly because Hyperion is not operating under a 301(h) waiver. The overall objectives of this NPDES monitoring program are to:

- determine compliance with NPDES permit terms and conditions; and
- determine that state water quality standards are met (40 CFR 122.41[j] and 12.48[b].

As in Orange County's permit, subsidiary objectives are specified that generally parallel those described in Table 4-3. However, Hyperion's NPDES permit (No. CA0109991) contains one important difference. It incorporates language stating that the monitoring program may be modified based on information generated by the program. This is an important source of flexibility that is discussed in greater depth in Chapter 6. Specifically, the permit states:

> Once an adequate background database is established and predictable relationships among the biological, water quality, and effluent monitoring variables are demonstrated, it may be appropriate to revise the monitoring program. Revisions may be made under the direction of the EPA and the Regional Board at any time during the permit term, and may include a reduction or increase in the

TABLE 4-4 Monitoring Program for Hyperion (1987)

Monitoring program	Parameters	Frequency
Shoreline water quality (17 stations)	Total and fecal coliforms, enterococcus, temperature, visual observations	Daily
Nearshore water quality (11 stations)	Total and fecal coliforms, enterococcus, temperature, DO, transmissivity profiles, visual observations	Weekly
	Above parameters plus suspended solids, oil and grease	Monthly
Offshore water quality (25 stations)	Profiles for DO, temperature, salinity, pH, visual observations	Weekly
Microlayer (12 stations)	Profiles for transmissivity and transparency; discrete samples for ammonia-nitrogen, suspended solids, TOC, oil and grease	Monthly
Sediment chemistry (39 stations)	Three replicate samples for oil and grease and TOC	3 times per year
(subset of 7 stations)	TOC, H_2S, oil and grease, grain size, 122 priority pollutants (one sample)	Annually
Sediment biology (39 stations)	Three replicate samples for above sediment parameters	Quarterly
(subset of 7 stations)	Macrofaunal community analysis (one sample)	Semiannually
		Quarterly
Demersal fish and macroinvertebrates (trawling) (6 stations)	Five replicates for macrofaunal community analysis	Quarterly
	Duplicate trawls for community analysis	Semiannually
Contaminants in sport fish (rig-fishing) (2 sites)	Three replicates for priority pollutants in tissues of hornyhead turbot and ridgebacked prawn	Semiannually
	Three replicate samples for priority pollutants in muscle of selected sport fish	

DO = dissolved oxygen; TOC = total organic carbon

(Table 4-4)

number of parameters to be monitored, the frequency of monitoring, or the number and size of the samples collected.

In addition to this permit language related to flexibility, the Hyperion program also includes a chemical sampling plan that allows monitoring resources to be used more efficiently. In the first year of the program, the entire list of priority pollutants is sampled in the effluent, the sediments, and selected organisms. In the second and third years, only those pollutants found during the first year are sampled for. Then in the fourth year, the entire list of pollutants is sampled for again. The rationale for this approach was to focus monitoring effort on those pollutants that occur in the effluent and the environment.

Coastal Power Plants

The history of monitoring of heated cooling water discharges from coastal electric power plants is much less involved than that for sewage discharges. Conventional generating stations on the shore of the bight were all completed before 1971. Between 1971 and 1973, thermal effects monitoring programs were required by the regional boards. Temperature profiles were measured in the water column; sediment grain size distribution was measured; and infauna, epifauna, plankton, and nekton communities in the vicinity of the outfalls were investigated. Some power plants continued these studies on their own through 1978, but others monitored only entrainment of fish in the water intakes. At the Encina generating station, a study of effects of thermal discharges on the giant kelp community was initiated in 1975 and continued through 1986.

In 1978, new NPDES permits were issued and annual monitoring programs were begun at most power plants (Table 4-5). As described below (see "The Research Sector"), the Southern California Edison Company (SCE) maintains an extensive program of special studies to develop information to supplement that gained through the monitoring programs.

San Onofre Nuclear Generating Station

The San Onofre Nuclear Generating Station (SONGS), located on the coast south of San Clemente, includes three units: Unit 1 was put in operation in 1968, and Units 2 and 3 came on line in 1985. The three reactors have enormous cooling-water requirements. The once-through seawater cooling system takes in approximately 6,300 m^3/s from nearshore intakes. The diffusers for Units 2 and 3 are unique to the bight. Each is approximately 0.6-mi long. In order to meet California thermal plan (State Water Resources Control Board, 1975) requirements, they were designed to entrain a volume of water 10 times the original discharge flow.

TABLE 4-5 NPDES Monitoring Programs at 10 Coastal Power Plants in the Southern California Bight[a]

Generating station	Max flow (MGD)[b]	Water column	Sedi-ments	Infauna	Epifauna and fish	Kelp
Alamitos	1,270	12 stations	grain size; 5 stations	4 stations; 4 repetitions	7 stations; 2 repetitions	No
Ormond Beach	688	8 stations	7 stations	6 stations; 4 repetitions	6 stations; 2 repetitions	No
Long Beach	772	8 stations	grain size; 6 stations	6 stations; 4 repetitions	3 stations; 2 repetitions	No
Mandalay	255	15 stations	5 stations	5 stations; 4 repetitions	3 stations	No
Scattergood	495	12 stations	grain size; 4 stations	4 stations; 4 repetitions	2 stations; 2 repetitions	No
El Segundo	606	12 stations	No	4 stations	12 stations	No
Redondo Beach	1,140	16 stations	grain size; 7 stations	7 stations	6 stations; 2 repetitions	No

Huntington Beach	519	3 stations	Metals, organics and grain size; 6 stations	3 stations	3 stations; 2 repetitions	No
SONGS	3,268	Temp and transmissivity at 22 stations; DO[c] & pH at 4 stations quarterly. Metals 5 stations and chlorine 8 stations triannually	No	No	Fish, 9 stations bimonthly	Acoustic at 3 stations semi-annually
Encina	860	10 stations	No	No	No	Aerial photo

[a] Water column monitoring focuses primarily on temperature, dissolved oxygen, pH, and transmissivity, and does not include sampling for contaminants. Sampling at all plants except Huntington Beach and San Onofre is done semiannually, that is, once every two years. Huntington Beach is sampled every year during the summer, and San Onofre is sampled as indicated in the table. Also note that Huntington Beach and San Onofre, unlike the other plants, sample different numbers of stations for epifauna and fish.
[b] MGD = millions of gallons per day
[c] DO = dissolved oxygen

SOURCE: From SCCWRP, 1988.

The resultant plume is directed offshore and has been shown to severely influence nearshore circulation patterns in the vicinity of the plant.

Marine monitoring at SONGS has been more intensive than that at other coastal power plants. The programs carried out at SONGS have been unique in the bight in terms of the intensity of monitoring devoted to a single discharge.

Monitoring and special studies have been performed continuously at the site since 1963. In 1964, baseline environmental monitoring was performed prior to operation of Unit 1. These included profiles of temperature and water clarity in the water column; measurements of local ocean currents; and characterization of intertidal, subtidal hard bottom, and kelp communities.

In 1974 and 1976, monitoring determined the environmental effects of sand disposal and dredging for emplacement of the Units 2 and 3 outfalls. In 1976, the San Diego RWQCB issued NPDES permits, including receiving-water monitoring requirements, for all three units. Current NPDES monitoring requirements are summarized in Table 4-5.

Along with these NPDES monitoring requirements, SCE is obligated to carry out further monitoring by other agencies. Impingement of fish in the intakes is monitored for the California Department of Fish and Game. Periodic monitoring of radionuclides is required by the Nuclear Regulatory Commission. Most monitoring occurs within 6 mi of the plant, with reference stations at 30 or 37 mi. Direct radiation is monitored continuously; airborne radiation is monitored weekly; ocean water is monitored monthly; beach sand and bottom sediments are monitored twice a year; and tissues of nonmigratory marine animals are monitored quarterly.

In addition, the California Coastal Commission required Southern California Edison to form the Marine Review Committee. This independent committee was established in 1974 by the California Coastal Zone Conservation Commission (now called the California Coastal Commission) in response to controversy about, and as a condition of, the permit for discharge of cooling water from SONGS Units 2 and 3. The specific responsibility of the committee was to protect marine life and resources from potential or actual damage directly related to the design and operation of the cooling water system of Units 2 and 3. Its studies focused on four areas:

1. determining the effects of SONGS Unit 1 on the marine environment,
2. predicting the effects of Units 2 and 3 on the marine environment and recommending needed design changes in the cooling water system to the California Coastal Commission,

3. determining the effects of SONGS Units 2 and 3 by performing both pre- and post-operational monitoring programs, and

4. investigating possible mitigation and enhancement measures for any damage encountered.

An important feature of the committee was its authority to make recommendations about operational and design changes to the cooling system, up to and including the construction of cooling towers.

The Marine Review Committee's program was noted for intense and comprehensive investigations, length of time committed to the study, and magnitude of total expenditures. Virtually all aspects of the marine environment near SONGS were investigated, including soft- and hard-substrate benthos, ichthyoplankton and adult fish, kelp beds, phytoplankton, zooplankton, epibenthic plankton, and the physical and chemical oceanography of the coastal zone. Investigations began in 1974, and study designs were, in most cases, firmly established by 1979. The resulting data sets cover eight years, and total expenditures for the program through production of the final report are estimated to be $47 million.

The committee's studies are unique among large monitoring programs in the bight in several important ways. First, the program was several times larger than any other monitoring program in the bight. Second, because the MRC was an independent entity, program designs could be adapted as needed. Third, monitoring plans were deliberately devised to detect predetermined amounts of change. Finally, repetitive, time series monitoring was integrated with modeling and research to constantly improve the ability of the monitoring programs to detect change.

Field work on nearly all projects was completed in December 1986, and final contractor reports were due in December 1987. The final report of the committee was scheduled for submission to the California Coastal Commission in 1989. Coincident with the end of the committee's studies, Southern California Edison began implementing procedures to make the committee's data available to investigators.

Oil Exploration and Production

There are few ongoing monitoring programs in the bight associated with oil exploration and production. This is partly because, except for platforms in the Santa Barbara Channel, the nearshore THUMS project in Long Beach, and the Aminoil project in Huntington Beach, there is no oil production in the nearshore regions of the bight. In addition, there are relatively few refineries along the coast discharging directly into the ocean. Finally, further exploration in the offshore regions of the bight has been delayed pending resolution of conflicts between the state and the federal government over oil and gas development policy for California's outer continental shelf.

EPA Region IX is considering the establishment of a monitoring program in the Santa Barbara Channel where extensive oil production occurs. The program's objectives will be to document production impacts from existing platforms and follow recovery after drilling ends. The THUMS project in Long Beach monitors a range of water column and sediment parameters at six stations. Sampling began before disposal. In the water column, salinity, temperature, pH, and dissolved oxygen are measured continuously, while heavy metals, oil and grease, suspended solids, cyanides, and organohalogens will be monitored quarterly during the first two years of the program. In the sediments, a range of parameters—including barium, EPA priority pollutants, grain size, petroleum hydrocarbons, and BOD—will be monitored semiannually. The Aminoil project in Huntington Beach measures grain size, barium, and heavy metals, and collects five replicate cores for infauna analysis at six sediment sites annually.

In Carpinteria, in the northern region of the bight, Chevron monitors water column, sediment, infauna, and epifauna parameters annually at four stations in the vicinity of the discharge from its wastewater treatment plant. The plant discharges 0.6 million gal/day of treated oil process waste. Water column variables measured include temperature, transmissivity, dissolved oxygen, pH, and ammonia. Sediment variables measured include sulfides, grain size, heavy metals, BOD, total organic carbon, total nitrogen, nitrate, oil and grease, and aromatic hydrocarbons. Infauna samples are identified to species, biomass is measured, and large epifaunal algae are identified.

Chevron also operates a refinery at El Segundo, in Santa Monica Bay. Organic matter is measured annually at two offshore sediment stations. In the water column, temperature, oil and grease, dissolved oxygen, and pH are measured monthly at four shore stations and two offshore stations.

Ocean Dumping and Dredge Disposal

There are no long-term ocean dumping monitoring programs for offshore sites in Southern California. Ocean dumping in the bight is currently limited to dredge material disposal. Two of the three active dredge dumpsites (LA2 and LA5) have only been sampled as part of the EIS/EIR process to designate them as permanent disposal sites. The first environmental survey of the third site (LA3) is currently in progress. The designation of LA2 and LA5 dump sites expired at the end of 1988, leaving only LA3 available to receive material from new projects. Routine ocean monitoring at the dump sites is under consideration by both EPA and the U.S. Army Corps of Engineers.

Dredge permit applications do not require monitoring at the dumpsite.

They do require chemical, bioaccumulation, and bioassay testing at the dredging site, in order to determine the suitability of the material for ocean disposal.

Nonpoint Sources

Nonpoint sources of contaminants are those that are diffuse or poorly defined. They include rainout or fallout from the air, surface runoff from land, and multiple small inputs, such as those from individual houses, businesses, and farms. Monitoring nonpoint source contamination is difficult precisely because it is so diffuse. It is technically challenging both to monitor such contaminant input and to clearly identify sources of elevated levels found in the environment.

Nonpoint sources are attracting greater attention from both regulatory agencies and the public, with most of this attention devoted to storm drains and riverine input. As a result of a steady decrease in the mass emissions from coastal wastewater treatment plants, mass emissions of some chemicals from stormwater runoff now approach those in effluents from coastal wastewater treatment plants (Table 4-6). As described in Chapter 1, precipitation in Southern California is highly seasonal. As a result, during dry periods a significant percentage of riverine flow can be composed of secondary and tertiary treated municipal wastewater from inland sewage treatment plants. Such inland treatment plants discharging to the Los Angeles or San Gabriel rivers may have flows in the range of 20 to 100 million gal/day.

As Garber (1987) points out, stormwater and riverine drainage enters the nearshore zone directly, while treated municipal wastewater is discharged 2 to 7 miles offshore, usually in deep water (about 100 ft). Potential impacts on recreational beaches may therefore be greater from land runoff than from offshore discharge of treated waste water.

In spite of these potential impacts, there is presently no mandated responsibility for monitoring land runoff. Individual county agencies responsible for stormwater systems may voluntarily perform such monitoring. For example, in Los Angeles County the County Department of Public Works monitors drainage facilities, and in Orange County such monitoring is performed by the County Environmental Management Agency. The only existing statutory basis for managing storm drainage systems is the NPDES permit program. However, agencies with overall management responsibility for stormwater drainage systems (e.g., Department of Public Works) are not now required to administer NPDES permits granted by other agencies for the multitude of individual discharges to the drainage system. There is thus no clear responsibility to monitor the drainage system itself or its discharges to the ocean.

TABLE 4-6 Estimated Average Emissions in Metric Tons Per Year of Several Constituents from the Los Angeles River and from the Two Largest Municipal Sewage Treatment Plants Discharging to the Southern California Bight

	Los Angeles River				
Constituent	1971/1972	1979/1980	1984/1985	JWPCP[a]	Hyperion[b]
Total extractable organics	---	6,400	28,600	7,860	13,200
Total aliphatics	---	---	270	---	---
Naphthalenes	---	---	0.29	---	---
Polynuclear aromatics	---	---	2.4	---	---
Total DDT	0.27	0.10	0.02	0.22	0.02
Total PCBs	0.75	0.09	0.01	0.21	< 0.12
Silver	< 1.0	< 1.0	< 1.0	4.5	12
Cadmium	3.7	1.2	< 1.0	3.8	8.2
Chromium	24	30	11	53	64
Copper	38	25	15	43	131
Iron	5,060	14,700	4,050	---	---
Manganese	137	188	78	---	---
Nickel	22	18	5.5	53	49
Lead	273	45	32	24	41
Zinc	153	139	81	131	151

[a]Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County, Palos Verdes, California.
[b]Hyperion Wastewater Treatment Plant, City of Los Angeles, Playa del Rey, California.

SOURCE: SCCWRP, 1986c.

Currently, nearly all NPDES-permitted discharges to drainage systems in the bight have strict effluent limitations and dischargers are required to do effluent monitoring. For example, all municipal wastewater treatment plants discharging to the river/stormwater system in Southern California measure priority pollutants in effluent semiannually and volatile organics quarterly. The 1987 amendments to the Clean Water Act require more monitoring of stormwater discharges.

The Los Angeles County monitoring program provides an example of the type of voluntary monitoring performed by agencies managing stormwater drainage systems in Southern California. Los Angeles County encompasses a drainage area of 4,100 mi^2 with a population in excess of eight million. Drainage of the area, primarily into the Southern California Bight, is provided by several rivers (such as the Los Angeles and San Gabriel rivers) and an extensive system of underground drains and open channels. The main flows to this system are from:

- precipitation;
- NPDES-permitted discharges of treated industrial and municipal wastewater;
- fire-fighting waste water (often containing high concentrations of contaminants);
- nuisance water (e.g., wash-down, excess lawn watering, etc.);
- accidental sewer overflows; and
- daily, weekly, and other periodic plant and site cleanup and wash down from business, commercial, and residential sources.

The Los Angeles County Flood Control District (since renamed the Los Angeles County Department of Public Works) began monitoring the drainage system in the 1930s because some of the runoff was used for groundwater recharge. In the mid 1960s, the water quality program was expanded to consider ocean disposal of stormwater runoff. The monitoring program was greatly reduced between 1984 and 1987, but much of it was reinstituted in 1988.

Water samples are collected during two to four storms per year from 20 stations along rivers, creeks, and drains. They are analyzed for inorganic minerals and pH, bacteria (total and fecal coliforms and enterococcus), total petroleum hydrocarbons, 12 heavy metals, total organic carbon, BOD, 8 volatile organic compounds, 15 pesticides, total suspended solids, and volatile suspended solids. Samples from the Rio Hondo Channel and San Gabriel River are also analyzed for priority pollutants.

Samples of dry weather (non-storm) flows are collected from 27 stations every month. These samples are analyzed for minerals, bacteria, total petroleum hydrocarbons, heavy metals, and oil and grease. Total organic carbon, BOD, and volatile organic compounds are analyzed quarterly or semiannually.

Shoreline Erosion and Beach Replenishment

The U.S. Army Corps of Engineers (COE) and the California Department of Boats and Waterways carry out the Coast of California Storm and Tidal Wave Program. This is intended to be a long-term program to develop baseline information on changes in beach profiles and ocean conditions along the California coast. The data will be used to monitor beach erosion and to assist in planning beach replenishment activities.

Approximately 60 sites between Oceanside and the U.S.-Mexican border were monitored semiannually between 1983 and 1988. Profiling efforts are expected to move to Orange and Los Angeles counties for the next five years. Semiannual monitoring of beach profiles in association with a sand bypass project at Oceanside Harbor has occurred since 1985 and may continue in the future.

A related program is carried out by the Ocean Engineering Research Group at the Scripps Institution of Oceanography, which monitors wave climatology at ten nearshore and offshore sites in Southern California. This project has collected over 10 years' worth of data for use by mariners and in coastal physical and oceanographic studies. The project is funded by the U.S. Army COE and the state of California.

Resource Monitoring

Resource monitoring is the responsibility of the California Department of Fish and Game, which collects information on sport and commercial fish catches and on exploitation of kelp beds in the bight. The present system of collecting catch information is straightforward and is described below, however the history of fisheries monitoring in California is long and complex. It is intimately associated with the California Cooperative Oceanic Fisheries Investigation (CalCOFI) program, which is unique for the spatial extent and consistency through time of its investigations into oceanography and fisheries biology. This history is summarized below and recounted in more detail in SCCWRP (1988).

Current Resource Monitoring

Commercial fishermen are required to report catch statistics to the Department of Fish and Game. Both fin and shellfish (e.g., abalone, sea urchins, lobsters) are included in these reporting requirements. Finfish catches have been monitored since 1918, and statistics currently include species caught and the location and weight of the catch. Daily logs of sea urchin and lobster catch numbers and locations have been reported for at least the last 10 years.

Commercial party-boat operators in the sport fishery are required to keep a log of the number and species of fish caught, number of anglers fishing, hours fished, and area fished. These records have been kept continuously by the Department of Fish and Game since 1935, with the exception of the five years during World War II (Young, 1969; Clark, 1982).

In 1975, the department initiated the Southern California Independent Sport Fishing Survey to monitor catches by recreational anglers. In 1979, the department, in collaboration with the National Marine Fisheries Service (NMFS), began a statewide program to monitor recreational catches. The objectives of these programs were to determine the magnitude and composition of the catch, to estimate effort expended by anglers and divers from private boats, and to assess the degree of compliance with state fishing laws (Wine, 1979).

Monitoring of artificial reefs began off Southern California in the late

1950s, in order to test the effectiveness of artificial reefs in increasing the availability of marine organisms and improving fishing. This program ended in 1964 and no formal studies were undertaken for 15 years, although reef building continued. In 1979, the Department of Fish and Game, in conjunction with Southern California Edison, began a six-year monitoring study of the development of marine life on the Pendelton Artificial Reef near the San Onofre Nuclear Generating Station. The objective was to develop a method of mitigating potential losses of kelp beds due to power plant operations. The success of this study resulted in an expanded program by the department to build and monitor artificial reefs throughout the Southern California Bight (Grant, 1987). This monitoring program is designed to identify the effects of important variables such as depth and reef topography on the biological communities that colonize reefs.

Historical Monitoring and the CalCOFI Program

Monitoring of marine fish and shellfish resources in the Southern California Bight has continued for more than 70 years. This monitoring has almost from the beginning been closely associated with research programs on fisheries. For this reason, the CalCOFI program is described here rather than in the research section below. In 1914, the California Department of Commercial Fisheries was established to collect fisheries statistics, develop improved methods for catching and processing fish, and study the life histories of commercially important fish and shellfish (Hewitt, 1988). Beginning in 1918, the Department of Commercial Fisheries collected catch data from commercial fishermen and fish dealers on species composition, weight, gear type, location, and intended commercial use. Much research was also performed during the 1920s and 1930s on fishery stock size, year class abundance, and fish distribution along the Pacific coast.

After World War II, state fishery agencies in California, Oregon, and Washington formed the Pacific Marine Fisheries Commission, and were later joined by fishery agencies in British Columbia. The commission's original focus was to study the Pacific sardine fishery, but when the fishery collapsed in 1947, it turned its attention to salmon, albacore, bottomfish, Dungeness crab, and shrimp (Croker, 1982).

After the sardine fishery collapsed, the California State legislature established the Marine Research Committee, composed of members from the commercial fishing industry and the California Department of Fish and Game. The committee set up a Fish and Game Preservation Fund to support research to improve the commercial marine fisheries of California and develop new commercial marine products.

In 1948, the committee established the California Cooperative Sardine Research Program. Its purpose was to study the distribution and natural history of sardines, their availability to the commercial fishery, fishing methods, and the physical, chemical, and biological oceanographic processes influencing sardine populations off California. The program included members from the California Department of Fish and Game, the Federal Bureau of Commercial Fisheries, Hopkins Marine Station, the California Academy of Sciences, and Scripps Institution of Oceanography. In 1953, the program was renamed the California Cooperative Oceanic Fisheries Investigation (CalCOFI) and was expanded to include consideration of species other than sardines. By 1960, CalCOFI's objectives had evolved to understanding factors governing abundance, distribution, and variations of pelagic marine fishes, emphasizing the oceanographic and biological factors affecting sardines and other marine life in the California Current system (Baxter, 1982).

The Fisheries Conservation and Management Act of 1976 (FCMA) gave the federal government management authority over commercial fisheries in the exclusive economic zone (the EEZ, 3 to 200 mi from shore), superseding the management role of the Marine Research Committee. The FCMA established regional fisheries management councils to develop plans for regulating harvesting of commercially valuable fish stocks and for controlling access of foreign fishing or processing vessels to U.S. territorial waters.

However, the NMFS, the California Department of Fish and Game, and Scripps decided in 1979 to continue CalCOFI as a long-term marine resources monitoring and research program (Radovich, 1982). The scope of and funding for the program have been greatly reduced in recent years (Figure 4-1). Fisheries and oceanographic data continue to be entered into the CalCOFI online data system at the Southwest Fisheries Center in La Jolla. This system contains a large-scale, multivariate time series of physical, chemical, biological, and meteorological data from approximately 40,000 stations and 300 cruises in the eastern North Pacific Ocean, collected since 1949.

Cooperation with scientists from Mexican institutions remains an important part of the CalCOFI program. This includes joint scientific symposia and cooperative studies of anchovy abundance and sardine spawning stocks. In addition, Mexico's fishery agency, the Secretatiat de Pesca, has expressed interest in funding a reestablishment of the CalCOFI time series transects in Mexican waters that were discontinued several years ago.

Kelp Bed Monitoring

Kelp beds along the California coast represent both a recreational and a commercial resource. Because of kelp's unique characteristics, separate programs have been instituted to monitor this resource. The California

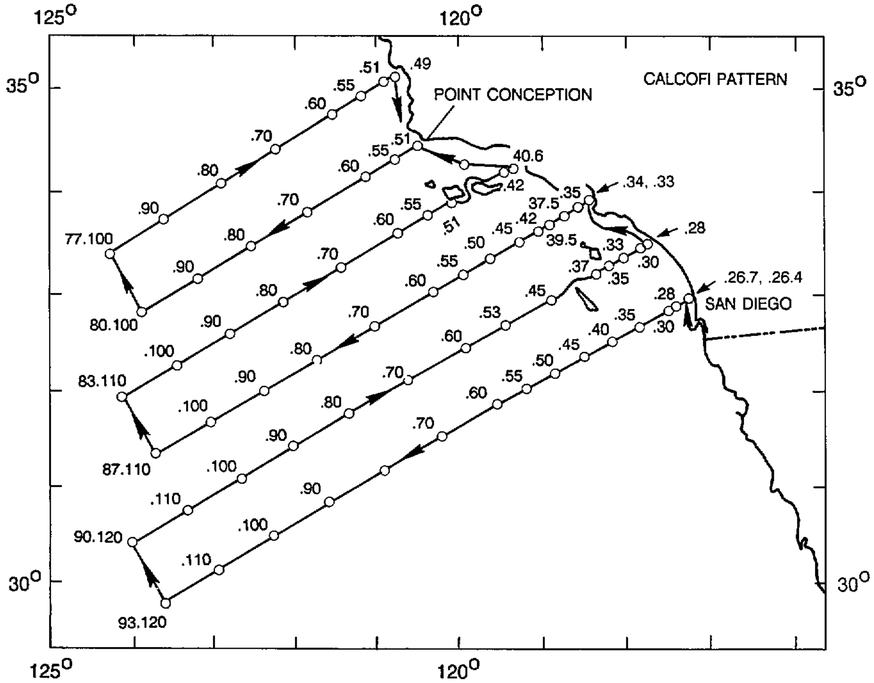

FIGURE 4-1 Location of the 1987 field survey stations sampled by CalCOFI during quarterly cruises. Station numbers and a typical cruise track are also shown.

Department of Fish and Game has conducted quarterly aerial surveys of kelp beds in Los Angeles County since 1974. Since 1987, these overflights have been extended south to San Onofre, near San Clemente. The goal of this program is to document fluctuations in bed size, and short-term studies have been conducted at the offshore islands and north of Los Angeles on special occasions.

In addition to these aerial surveys, diving surveys have been carried out since 1977 at five sites around the Palos Verdes Peninsula as part of the Nearshore Sportfish Habitat Evaluation Program. The goal is to increase understanding of kelp bed ecology.

In San Diego County aerial surveys have been carried out quarterly since 1967 by Dr. Wheeler North of the California Institute of Technology in Pasadena. These data are used by the six municipal dischargers in the county to fulfill NPDES monitoring requirements.

The Kelco Co. of San Diego compiles kelp harvest data by month and by kelp bed. However, only total annual values are available to the public due to lease agreements between Kelco and the state.

Noncommercial Resources

Another type of resource monitoring is mandated by Title III of the Marine Protection, Research and Sanctuaries Act (MPRSA) in the Channel Islands National Park. At the national park, long-term, time series monitoring is used to assess and maintain the ecological conditions (National Park Service, 1984). The main focus of the monitoring, much of it done with volunteers, is to determine the population dynamics and long-term environmental trends for key species of marine plants and animals in the park.

The National Estuarine Reserve Research Program of the Coastal Zone Management Act (CZMA) mandates research and monitoring programs in designated estuaries. In fiscal year 1988, the National Oceanic and Atmospheric Administration (NOAA) initiated a competitive grants program for studies in the 17 designated national estuarine reserves. The Tijuana River estuary is the only national estuarine reserve in the Southern California Bight area. Research and monitoring will be focused in five areas:

1. water management—the relationship between freshwater inflow and estuarine productivity;
2. sediment management—the effects of different types of sediments and sedimentation processes on estuaries;
3. nutrients and other chemical inputs—effects of anthropogenic inputs on estuaries;
4. coupling of primary and secondary productivity—nature of estuarine food webs and energy flows; and
5. estuarine fishery habitat requirements—values of estuaries as nursery areas for commercial and recreational species.

In the case of the Tijuana River estuary, these data will be extremely useful in influencing the design of sewage management strategies for Tijuana, Mexico (see "The U.S.-Mexican Sewage Contamination Problem," Chapter 2).

Water Quality Monitoring for Public Health

The California Health and Safety Code specifies that the State Department of Health Services is responsible for supervising sanitation, healthfulness, and safety of public beaches and public water contact areas of the state's bays and ocean waters. The State Department of Health Services may delegate some monitoring and enforcement activities to the county health services departments. When a public beach or water contact sports area fails to meet standards, the local health officer or the State Department of Health Services, after considering the causes of the failure, may post the area with warning signs or otherwise restrict use of the area until corrective action has been taken and the two following standards are met:

1. physical–no sewage sludge, grease, or other physical evidence of sewage discharge shall be visible at any time on any public beaches or contact sports areas; and
2. bacteriological–samples of water at a public beach or water contact sports area shall have a most probable number (MPN) of coliform bacteria less than 1,000 per 10 ml, provided that no more than 20 percent of the samples at any station in a 30-day period exceed 1,000 per 10 ml, and provided further that no single sample, when verified by a repeated sample taken within 48 hours, shall exceed 10,000 per 10 ml.

The monitoring programs performed by county health agencies in support of these management activities are of two types: (1) routine bacteriological sampling, and (2) bacteriological sampling following a waste discharge into recreational waters. Special studies are also carried out by county health agencies. However, there are no health monitoring programs targeted specifically at human health effects (e.g., gastroenteritis) related directly to water-contact sports.

Orange County has performed a monitoring program in recreational waters for several years. Los Angeles County is now monitoring routinely. In San Diego County, monitoring is performed along the shore at four sewage treatment plant ocean outfall sites: city of Oceanside, Encina Water Pollution Control Facility, San Elijo Water Pollution Control Facility, and city of San Diego. The outfall from the Point Loma Plant was constructed before kelp beds were included as water contact sports areas and the treatment plant is experiencing difficulty meeting bacterial standards at the outer perimeter of the kelp beds.

For over 30 years, the San Diego County Department of Health Services has performed beach and bay surveys annually. About 60 stations are usually sampled on these surveys. From three to five samples are collected at each station in April and May of each year. In addition, surveys of 40 stations, with a single sample from each station, are performed in early July and September. Many of these stations are interspersed with the shoreline stations sampled by the dischargers.

A routine weekly survey of water quality in Mission Bay was started in 1977 and continued through January 1987. The city of San Diego has replaced it with a more intensive monitoring program with more stations sampled more frequently. This monitoring program was initiated voluntarily by the city because of strong public concern about poor water quality. The data collected in all these monitoring activities is shared with the State Department of Health Services, regional water quality control boards, and other state and federal agencies concerned about recreational water quality.

National and Statewide Monitoring Programs

NOAA's National Mussel Watch Program and National Status and Trends Program represent national monitoring programs that have included sampling and measurement stations within the Southern California Bight. While the numbers of stations are too few to present a comprehensive picture of contaminant levels in the bight, they do provide a basis for making comparisons with contaminant levels in other parts of the country.

The original National Mussel Watch Program, developed by Dr. Edward Goldberg of Scripps and 10 other principal investigators, was first funded by EPA in 1976. Mussels and oysters were sampled at approximately 78 coastal and estuarine stations along the Atlantic, Gulf, and Pacific coasts of the United States in 1976, and again in 1977/1978. There were eight stations in the Southern California Bight. Mussel tissues were analyzed for six metals, three radionuclides, DDT (and its breakdown products), PCBs, and petroleum hydrocarbons (Goldberg et al., 1978a). Total funding for the program was about $400,000 per year. The national program was not continued past 1978, but several local programs were continued.

In 1984, NOAA's Ocean Assessments Division initiated the National Status and Trends Program that includes a National Benthic Surveillance Project and a Mussel Watch Project (NOAA, 1987). In the Benthic Surveillance Project, sediments and demersal fish have been collected annually since 1984 from 50 sites along the U.S. coast, including Alaska. In the Mussel Watch Project, mussel and oyster samples have been collected once each year since 1986 from 150 sites along the U.S. coast, including Alaska and Hawaii. Sediments are also collected at many of the Mussel Watch stations. There are 6 Benthic Surveillance stations and 16 Mussel Watch stations in the Southern California Bight (Figure 4-2). An extensive suite of metals (17), polynuclear aromatic hydrocarbons (18), pesticides (15), and PCBs is analyzed in the animal tissues and sediment samples. In addition, the fish are examined for diseases and histopathological lesions.

The overall objective of the National Status and Trends Program is to assess and document the status of coastal and estuarine environments. Specifically, the program is intended to define the geographic distribution of contaminant concentrations in biological tissues and in sediments from U.S. coastal and estuarine waters, determine temporal changes in those concentrations, and document biological responses to contamination (e.g., Malins et al., 1986). This information will be used to make decisions about the use and allocation of resources in the nation's coastal and estuarine regions.

Since 1976, the California Department of Fish and Game, under an interagency agreement with the California State Water Resources Control Board, has performed a Mussel Watch Program for monitoring marine and

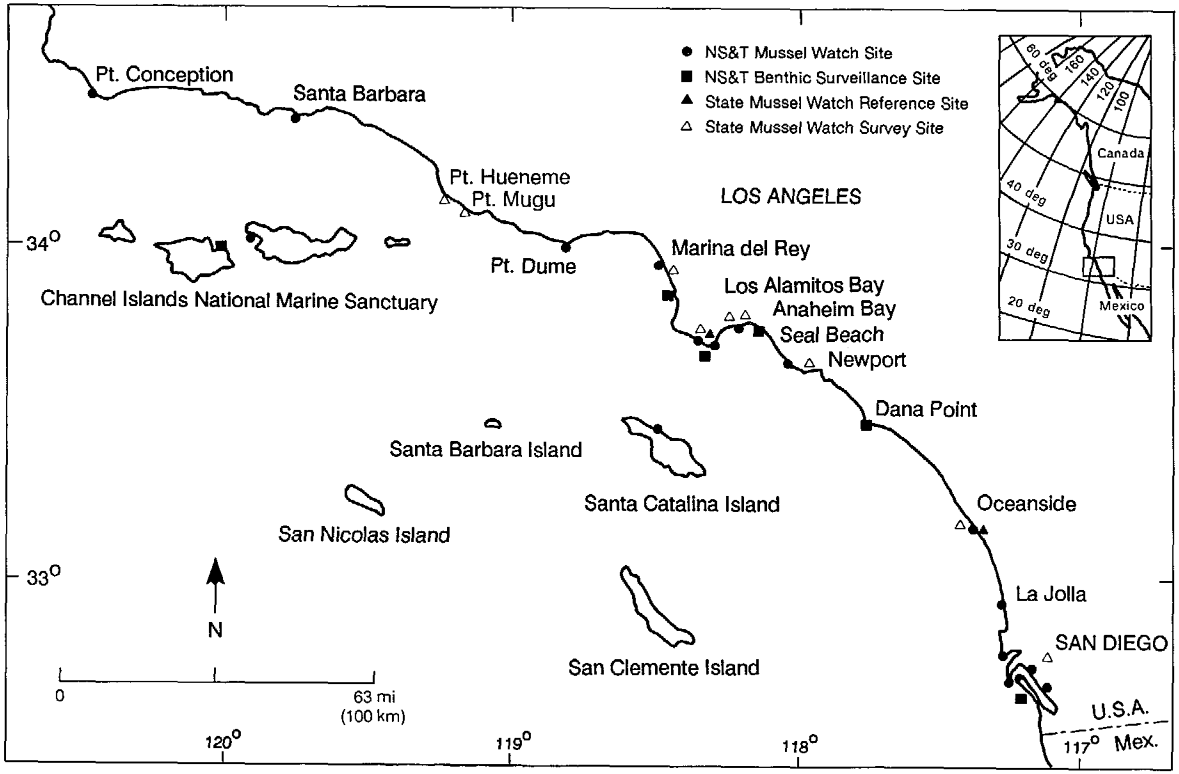

FIGURE 4-2 Locations of the NOAA National Status and Trends' Mussel Watch, and benthic surveillance sampling stations and the California Mussel Watch reference and survey sampling sites in the Southern California Bight. All California Mussel Watch Survey sites include several mussel sampling or transplant stations.

estuarine waters (Stephenson et al., 1987). Its purpose is to provide the state board and six coastal regional boards with an ongoing assessment of the geographic and temporal trends in levels of chemical contamination in coastal waters. The state's Mussel Watch Program is somewhat different than the national program in that it includes only five reference stations and several site-specific "hot spot" survey sites.

The latter may change from year to year. Resident mussels are used at the reference sites, but transplanted mussels or the Asiatic clam, *Corbicula fluminea*, are used at most site-specific stations. The two reference stations in the Southern California Bight are at Palos Verdes (Royal Palms State Park) and Oceanside. They are also National Mussel Watch sampling sites, providing an opportunity for intercalibration of results from the two programs. In 1986-1987, 11 site-specific surveys were performed in the Southern California Bight (Figure 4-2). These studies were performed at one or more locations inside harbors, marinas, or enclosed bays. All but two of the site-specific surveys were designed to collect baseline estuarine data. The survey in Los Angeles/Long Beach harbors was to document the levels of DDT, PCBs, and metals; the survey in San Diego Bay was intended to assess the level of contamination of PCBs, silver, copper, and zinc.

Citizen and Community Monitoring

Interest in the bight and its resources by community and environmental groups has extended to voluntary participation in monitoring and research programs. Three examples of these efforts have provided useful information.

Over 200 organizations and their personnel, mostly volunteers, monitor marine mammal strandings along the California coast as part of the Marine Mammal Stranding Network. The data generated by the Network are collected and managed by NOAA's Southwest Fisheries Center in La Jolla. Notification of strandings has been useful to scientists studying chemical contamination, diseases, and population trends of marine mammals (Seagars et al., 1986).

Volunteer reporting of physical evidence of sewage entering recreational waters has provided local health departments with timely information needed to determine whether to close recreational beaches and swimming areas.

Finally, annual volunteer beach cleanups coordinated by the California Coastal Commission have resulted in estimates of the type and quantity of plastic debris littering beaches. Such information has proven useful enough that the Center for Marine Education in Washington, D. C. plans to develop a uniform data reporting system for beach cleanups nationwide. These data will help in monitoring the magnitude of the plastic debris problem, as well as the effectiveness of source control and recycling programs. These efforts are supported officially, since Section 2204 of the 1987 Marine Plastic Pollution Research and Control Act directs the Secretary of Commerce, in cooperation with EPA, to encourage the formation of volunteer groups, to be designated as "Citizen Pollution Patrols," to assist in monitoring, reporting, cleanup, and prevention of ocean and shoreline pollution (1987 Marine Plastic Pollution Research and Control Act included as Title II in the U.S. Japan Fishery Agreement Approval Act of 1987).

Monitoring Expenditures

Marine monitoring programs are expensive, primarily due to staffing needs. Trained scientists and technicians are required to conduct field sampling, perform laboratory analyses, interpret resulting data, and write reports. Many activities involved in monitoring, such as benthic infaunal analysis and analytical chemistry, are labor-intensive. Tetra Tech (1984) estimated the costs to perform representative monitoring activities to be:

- $200 to $1,200 for a single benthic infaunal analysis; and
- $920 to $2,300 for a single priority pollutant scan of sediments.

These estimates are low compared to current rates, but they do show that monitoring is not cheap. In the Orange County 301(h) monitoring program, 300 benthic infaunal samples and 196 sediment chemistry samples are analyzed each year. Assuming that each benthic sample costs $600 and each chemistry sample costs $1,500 to analyze, the total cost per year to analyze these samples alone is $474,000.

Equipment and facilities that must be purchased are also costly. A good gas chromatograph, needed to measure PCBs, DDT, and other organic contaminants, may cost $10,000 to $50,000. An atomic absorption spectrophotometer, used to analyze metals, will have a similar cost. Research vessels equipped for accurate navigation and for collecting diverse sample types may cost $2,000 to $5,000 per day for an offshore vessel and $500 to $1,000 per day for a smaller vessel suitable for sampling close to shore.

Table 4-7 summarizes estimated costs incurred during the last five years in different types of monitoring in the Southern California Bight. This summary is incomplete, since it does not include several voluntary (nonmandated) monitoring programs and research efforts performed by different dischargers, environmental agencies, or universities. In addition, the costs of effluent monitoring activities are probably under-recorded, since they often are not consolidated with receiving water monitoring budgets.

Facilities and overhead costs for those aspects of monitoring performed

TABLE 4-7 Estimated Costs for Monitoring Programs in the Southern California Bight

Program/location	Costs in thousands of dollars				
	1983	1984	1985	1986	1987
Waste treatment plants					
Point Loma	496	766	1,129	1,935	1,332
CSD Orange County	270	269	1,206	1,894	1,954
CSD Los Angeles County					
--required	350	373	351	434	750
--voluntary	450	503	479	522	350
Los Angeles City Hyperion	530	583	767	809	890
Aliso, South Laguna Beach	---[a]	43	44	33	34
Oxnard	---	---	103	214	277
SERRA, Dana Point	---	31	24	27	31
San Elijo	---	---	---	---	32
Encina	5	5	8	135	134
Goleta	14	17	47	170	270
El Estero	---	---	---	---	50
Electricity generating plants					
San Onofre nuclear plant, Southern California Edison, required and voluntary	1,100	1,100	1,100	1,100	1,100
San Onofre, Marine Review Committee	6,000	6,000	6,000	6,000	6,000
Southern California Edison, 7 generating stations					
--full program	540	540	540	540	540
--fish and bioassay	200	200	200	200	200
Scattergood Generating Station	---	---	12.5	12.5	---
Encina, San Diego Gas and Electric	---	---	---	---	25
Thermal outfalls	---	---	---	---	200
Redondo Harbor	---	---	---	---	20
Industrial discharges					
THUMS	---	---	---	---	---
Natural resources					
Channel Islands	---	---	---	---	45
CalCOFI (based on 60 days at sea, $9,000/ day ship time)	---	---	---	---	540
State mussel watch	325	328	331	334	340

TABLE 4-7 Continued

Program/location	Costs in thousands of dollars				
	1983	1984	1985	1986	1987
California Fish and Game					
Pendleton reef	---	---	---	---	280
1900s	---	---	---	---	530
pelagic fish	---	---	---	---	175
party boat survey	---	---	---	---	55
sportfish management	---	---	---	---	360
fishery assessment	---	---	---	---	800
Pacific Marine Fisheries committee recreational fishery statistics	---	---	---	---	250
Public health					
Long Beach	---	---	---	---	80
Orange County	---	---	---	---	150
San Diego	---	---	---	---	80
Total					17,874

*--- data not available.

SOURCE: SCCWRP, 1988.

in-house by municipal wastewater treatment plants and industrial dischargers usually are not reported. While an accurate accounting of overhead costs is not available, these have been estimated to be equivalent to the direct costs, effectively doubling the total. Expenses incurred by county public works departments in monitoring chemicals in stormwater runoff are also not included in Table 4-7. Costs for the NOAA Status and Trends (Mussel Watch) monitoring of mussels, sediments, and fish in the bight are not included. (The estimated cost for sampling all stations in the bight and analyzing the samples is $175,000 per year.) Despite these omissions, the costs summarized in Table 4-7 do give a rough impression of the minimum level of expenses incurred in monitoring water quality, natural resources, and public health.

Table 4-7 reveals some important facts. Total estimated costs in 1987 for all monitoring in the bight are over $17 million. Because of the large budget of the Marine Review Committee's study of SONGS (ending in 1989), monitoring costs for the electric utilities are higher in this year than for the municipal wastewater treatment plants. Among the treatment plants, the most expensive monitoring program, at nearly $2 million per year, is the 301(h) monitoring program being performed by the County Sanitation Districts of Orange County. Total natural resource assessments cost about $3.3 million per year, while public health monitoring by the separate counties costs about $310,000 per year.

Of the total annual monitoring expenses of over $17 million in the Southern California Bight, nearly 80 percent are borne by the public sector. Much of the remainder is spent by the California Department of Fish and Game for marine resource monitoring.

Summary of Monitoring Activities

The review of monitoring activities in the Southern California Bight highlighted several important features that will be treated in more detail in the analysis of monitoring (Chapter 6). For the most part, monitoring is performed in response to permit requirements that regulate discharge activities. There are many agencies, federal, state, and local, involved in establishing standards and regulations under which these permits are administered. Despite the many agencies and programs, there is no overall coordination of monitoring in the bight. There is, however, cooperation among agencies that jointly regulate specific discharges such as the Hyperion outfall.

Individual monitoring programs are carefully carried out using state-of-the-art methods, and the quality of the resulting data is typically very high. Finally, Table 4-7 reveals that, with the exception of the recently ended Marine Review Committee program at San Onofre, the bulk of monitoring funds are devoted to measuring the effects of municipal wastewater discharge.

THE RESEARCH SECTOR

A great deal of research is performed in the bight by federal, state, and local agencies, and by universities and private industry. Some of this research is oriented specifically toward environmental problems (such as the effects of municipal wastewater outfalls) that are also addressed by monitoring programs. Other research is oriented toward more general issues in oceanography and marine ecology.

Research results can benefit monitoring programs by:

- increasing understanding of the marine environment and thereby enhancing the ability to predict, measure, and assess human impacts;
- identifying physical, chemical, or biological changes that are better indicators of pollution impacts than the parameters currently used in monitoring programs;
- providing information on the character and variability of natural processes in the marine environment that can be used as references against which to compare changes due to human activity;

• establishing a link or correlation between a parameter measured in a monitoring program and an adverse outcome of concern to society (e.g., link between fecal coliforms and disease);

• determining whether measurements made in monitoring programs provide meaningful assessments of the health of the marine environment and the nature of human impacts on it; and

• developing new techniques and instrumentation for use in monitoring programs.

The research sector is even more diverse than the monitoring sector, with a wide variety of programs that span the range from large-scale studies carried out by multidisciplinary research groups to narrowly focused studies performed by individual scientists. The following sections describe representative research activities sponsored by federal, state, and local agencies, universities, and private industry. This is not meant to be an exhaustive listing of programs and certainly does not come close to describing all the research carried out in the bight.

Federal Agencies

Marine research in the bight is sponsored by the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the Minerals Management Service (MMS), the Department of Energy (DOE), and the Fish and Wildlife Service (FWS).

The NSF funds individual investigators as well as research programs and institutes at universities throughout the bight. This research is described more completely in the section below on university research.

NOAA funds several important programs in the bight. The National Status and Trends Program was described above as part of the monitoring sector. In addition, NOAA funds the National Marine Fisheries Service (NMFS) and the Sea Grant College Program.

NMFS performs studies of the biology of commercially important fish species and of the relationships between stocks of these species and the physical and chemical oceanography of the bight. Such studies include investigations of habitat requirements, reproduction, feeding biology, population dynamics, geographic distribution, and response to contaminants. NMFS is also an active participant in the CalCOFI program, which combines monitoring and research focused on commercial fisheries (see Historical Monitoring and the CalCOFI Program above). Because of its long history, archived samples from the CalCOFI program have proven valuable in studies of trends of contaminants such as DDT.

NOAA also funds the Sea Grant College Program, which is administered through the University of California. The federal Sea Grant legislation requires that at least one-third of the total federal funds received by each program be matched with local (nonfederal) funds. Since 1973, the state of California has made successive five-year commitments to provide up to two-thirds of the required matching funds (University of California, 1989). Sea Grant studies have addressed a wide variety of coastal problems, including, at present, the functioning of wetlands, physical processes in the coastal zone, aquaculture, marine products chemistry, and ocean engineering.

The U.S. EPA funds research targeted at specific environmental problems. This research is not extensive compared to that carried out by other agencies, since EPA's regional activities are predominantly enforcement related. As an example of such targeted research, EPA supported a study in 1980 to investigate fish catch and consumption among population subgroups in the Los Angeles area. The study was designed to furnish information useful in formulating local regulatory approaches, and was motivated by awareness that certain parts of the local population consume larger than average amounts of locally caught seafood containing elevated concentrations of DDT and PCBs (Puffer et al., 1982, 1983; Puffer and Gossett, 1983; Gossett et al., 1983). In addition, research carried out at the various EPA research laboratories is often relevant to environmental issues in the Southern California Bight.

The Pacific Outer Continental Shelf Region of the MMS funds an Environmental Studies Program (established in 1973) designed to provide basic information needed to make management decisions about the outer continental shelf (F. Piltz, personal communication; Piltz, 1990; MMS, 1990). Although most of this region lies outside the boundary of the bight, some portions of these studies are carried out inside it. Southern California region studies have investigated air quality, potential toxicity of oil to seabirds and marine mammals, adaptation of marine organisms to chronic exposure to petroleum hydrocarbons, and the effects of geophysical acoustic survey operations on important commercial fisheries. In addition, MMS has carried out large-scale reconnaissance of benthic hard- and soft-bottom communities and assessments of long-term changes in benthic communities in oil and gas development areas. Some MMS studies (e.g., Fauchald and Jones, 1978) are notable for their wide geographic coverage and commitment to long-term data collection.

The Ecological Research Division of DOE is sponsoring three regional studies in the bight. One of these, the California Basin Study (CaBS), begun in 1985, is a multidisciplinary effort to examine and understand the production, transport, and ultimate fate of biogenic particulates and the energy-related products (e.g., radionuclides) associated with them. One of the major goals of CaBS is to develop a carbon budget for the Southern California Bight that incorporates the contributions of bacteria, phytoplankton, and zooplankton.

The U.S. FWS Biological Services Program has performed an ecological inventory of the entire Pacific coast, including the bight. The FWS has published several reports on critical habitats within the bight, including kelp forests and coastal marshes, and has developed a series of profiles of environmental requirements for coastal fishes and invertebrates.

State Agencies

Marine research in the bight is sponsored by the California Department of Fish and Game, the Water Resources Control Board, and the Department of Health Services. In addition, state funds contribute to the support of the Sea Grant College Program.

The Marine Resources Branch of the Department of Fish and Game conducts research designed to protect and enhance specific fishery resources. The department has studied the effectiveness of artificial reefs in enhancing fish stocks and evaluated various methods for rehabilitating kelp beds. In addition, the department participates in funding the CalCOFI program, which investigates the biology of commercial fisheries.

The State Water Resources Control Board funds research specifically related to identifying environmental problems and developing water and sediment quality criteria and regulatory standards. For example, the board has supported a survey of PAH levels throughout the bight, followed by laboratory studies of PAH uptake and toxicity. The board has also requested studies of sediment transport and alternative methods of establishing sediment quality criteria.

The California Department of Health Services has examined levels of chemical contamination in fish caught in Santa Monica Bay and Los Angeles and Long Beach harbors. The results of this investigation will be useful to EPA and the Food and Drug Administration (FDA) in revising action limits for some highly nonpolar organic contaminants, such as DDT and PCBs. These are of special concern because of their high potential for bioaccumulation and toxicity.

Local Agencies

The single largest and most focused body of research on pollution problems in the bight is that performed by the municipal and regional sanitation agencies and the research organization they jointly fund, the Southern California Coastal Water Research Project (SCCWRP). In addition, local public health departments conduct research into the health effects of marine contamination and the regional water quality control boards carry out occasional studies targeted at the development of regulatory criteria.

The four major sanitation agencies in the bight all maintain active marine research programs that are beyond the activities mandated by their discharge permits. These four agencies are Los Angeles City, the County Sanitation Districts of Los Angeles County, the County Sanitation Districts of Orange County, and San Diego City. These agencies typically fund research on questions that are relevant to the management of their discharges and the understanding or mitigation of environmental impacts. They consider this research necessary to answer questions that are not addressed by mandated monitoring programs. Research has included both field and modeling studies of sediment transport and plume behavior, as well as investigations of nutrient dynamics in the water column, sediment toxicity, benthic community structure, and kelp bed ecology. In conjunction with SCCWRP, Los Angeles City is currently conducting an experimental study of the rate and character of ecological recovery around the city's sludge outfall, which suspended discharge operations in November 1987. In addition to these active research programs, all discharge agencies in the Southern California Bight belong to the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT). This organization works to ensure that all studies use a consistent, standardized, and up-to-date species list of marine invertebrates. This list has proved invaluable in regional analyses, which otherwise would have been impossible to perform. Discharge agencies also are active members of the Southern California Environmental Chemists Society (SCECS), which performs an analogous function for environmental chemistry.

SCCWRP was founded in 1969 with the aim of conducting both basic and applied marine research relevant to the discharge of municipal wastewater to the bight. At present, SCCWRP is supported by a yearly allocation from the seven major municipal dischargers in the bight, and to a lesser extent by contract funds from state and federal agencies. SCCWRP investigates generic problems of interest to all the dischargers, develops and refines new methods, and performs regional analyses that are beyond the scope of individual dischargers. SCCWRP's work has resulted in important additions to knowledge about the marine environment and improvements to monitoring practice. For instance, SCCWRP researchers have evaluated alternative methods for sampling benthic communities and developed the Infaunal Trophic Index for characterizing the degree of change in benthic communities. They have also investigated histopathological and biochemical indicators of pollutant stress in marine species, documented pollution induced changes in reproduction of key fish species, and monitored regional trends in the incidence of effects such as fin rot and tumors on fish. SCCWRP has performed a vital function because of its ability to collect and integrate data from all the municipal dischargers in the bight. As a result, SCCWRP has been able to complete significant analyses of bightwide patterns and trends in contamination and environmental change. The periodic SCCWRP Report series is available to the public on request.

County health departments and municipal governments in the bight have carried out periodic research studies to assess the likelihood of specific health effects from environmental contamination. For example, the Los Angeles County Department of Health Services has carried out lifeguard surveys in response to inquiries about the health of lifeguards.[1] These studies were stimulated in part by the finding that seven lifeguards in the Los Angeles area had developed cancer. The department is currently planning an additional epidemiological study of lifeguards that will focus on short-term health outcomes. Lifeguards were chosen as a sentinel group for monitoring possible adverse health outcomes due to marine pollution because they are more heavily and consistently exposed than the general public to contaminants in the ocean. The department is also investigating the relationship between consumption of ocean fish and concentrations of DDT, DDE, and PCBs in the milk of lactating mothers.[2] Another example of research performed by local agencies is the city of San Diego's study to assess health risks from the municipal wastewater discharge at Point

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[1] In 1982, following notification that seven lifeguards in the Los Angeles area had developed cancer, Dr. Thomas Mack of the University of Southern California Cancer Surveillance Program undertook a study of cancer prevalence in Los Angeles County. He concluded that, although the number of cancer cases was higher than predicted, the elevation was not statistically significant. Neither was there evidence of a causal link between work as a lifeguard near Santa Monica beach and the subsequent appearance of cancer. In addition to these studies, investigations by the Department of Health Services have shown that industrial health claims demonstrate no clear pattern of illness in relation to where the lifeguards work. Prevalence of hepatitis A serology among lifeguards does not differ from control populations.

[2] Previous mammal studies showed that PCBs and DDT adversely affect neonatal development at doses that might be encountered by a small percentage of people eating contaminated fish from the bight (Allen and Barsotti, 1976). To address this concern, the Department of Health Services has selected approximately 50 post-partum breast-feeding women, predominantly from lower socioeconomic groups, as subjects in a study of the relationship between consumption of ocean fish and concentrations of DDT, DDE, and PCBs in breast milk. Preliminary results indicate that PCB concentrations (measured on a fat basis) are typically between 0.1 and 0.3 ppm. There are no values over 0.9 ppm. DDT is present in breast milk at concentrations from 1 to 5 ppm, with a few values over 10 ppm as measured on a lipid basis. It appears that the major source of PCBs in these women is the consumption of fishery products from the bight. However, there is an association between prior residence in Mexico or Central America and elevated (5 ppm or higher) concentrations of DDE in breast milk. All concentrations measured to date are well below the FDA action limits for whole milk (on a whole milk basis).

Loma to recreational divers who use the Point Loma kelp bed or consume seafood caught there.[3]

The regional water quality control boards, which act independently of the state board, occasionally support research targeted at specific local problems. As one example, the Los Angeles board recently funded a study of contaminants in river runoff in the Los Angeles basin.

Universities

The are more than 200 academic institutions in the region of the Southern California Bight. Some of these have extensive and diverse marine research programs, while others may have only one or a few marine scientists active in particular specialties. The great number and wide variety of the academic marine research programs carried out in the bight make it impossible to review this work in detail. The following paragraphs therefore summarize only those programs that are large, well known, or have contributed significantly to knowledge about the marine environment and environmental effects.

The Scripps Institution of Oceanography of the University of California (UC) system carries out the largest and most varied set of marine research programs in the bight. Scripps is one of the largest oceanographic institutions in the country. It coordinates Sea Grant projects carried out by schools in the UC system and is a member of the University National Oceanographic Laboratory System (UNOLS), partially funded by the National Science Foundation. The research performed at Scripps is worldwide in scope and the institution maintains a fleet of oceangoing research vessels. However, a significant proportion of this work is focused on the California Current system and the Southern California Bight.

Scripps has several large research groups that focus on particular aspects of marine studies. The Food Chain Research Group's focus is the food web dynamics and biogeochemical cycles of plankton, and the nature of environmental effects on these. The Marine Life Research Group focuses on understanding the distribution and variability of the living resources of the California Current system. This research is carried out primarily

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[3]Between June and September 1986, 346 recruited divers made 1,371 dives in the Pt. Loma kelp bed. Over 90 percent of the divers took seafood from the kelp bed and 25 percent of those who ate the seafood ate it raw. Raw seafood was consumed underwater by 18 percent of the divers. Twelve illnesses that fit the highly credible gastrointestinal symptoms (HCGI) as defined by EPA were reported. If all reported HCGI illnesses were genuine, then there were eight HCGI cases per 1,000 divers. The new EPA Water Contact Criteria that use enterococcus as the indicator organism for marine waters set a maximum allowable geometric mean enterococcus concentration that would permit an estimated 19 illnesses per 1,000 swimmers. The apparent health risk to divers in the Pt. Loma kelp bed is thus relatively low.

in conjunction with the CalCOFI Program. The Center for Coastal Studies emphasizes investigations of sedimentology and physical and chemical oceanography in the coastal zone. The goal of these studies is to increase the ability to assess and predict the effects of human activity in the coastal environment. In addition to these large groups, individual investigators at Scripps carry out research on the physical and chemical oceanography of the bight, as well as on the biology of kelp bed communities, fish populations, and other resources.

The University of California at Santa Barbara (UCSB) supports the Marine Science Institute and the Coastal Research Center. These research groups carry out basic and applied studies on specific marine resources such as kelp beds and fish stocks, as well as on more general problems such as the toxicity of pollutants. The Center for Remote Sensing and Environmental Optics is developing methods for applying remote sensing (i.e., satellite imagery) technology to the assessment of patterns and processes in the marine environment.

The University of Southern California (USC), a private institution in Los Angeles that is designated as a Sea Grant Institutional Program and is part of UNOLS, operates the Santa Catalina Island Marine Science Center. Historically, the USC Allan Hancock Foundation conducted pioneering programs emphasizing the coastal sedimentology and benthic ecology of the bight. USC has also conducted diverse applied studies, such as baseline inventories in marinas, harbors, and nearshore and continental shelf waters, and environmental assessments in support of the siting of the Hyperion Treatment Plant deepwater outfall and the Terminal Island Treatment Plant outfall. USC has also cooperated with the County Sanitation Districts of Los Angeles County in studies of the plume from the districts' White Point outfall. Other studies performed by USC researchers have examined the effects of oil seeps, the Santa Barbara oil spill, harbor dredging, and disposal of fish processing wastes.

The California State University (CSU) system, originally termed the State College system, is distinct from the University of California system. In the Los Angeles area, the State University system operates the Southern California Ocean Studies Consortium (SCOSC), which coordinates marine research, education, and community service programs at several state university campuses. The consortium recently completed a baseline biological survey for the Terminal Island dry bulk handling terminal in Los Angeles Harbor. Prior to and since the formation of SCOSC, faculty at CSU Long Beach have studied the effects of pollution on nearshore benthos and on reproduction of benthic invertebrates and have developed alternative bioassay/toxicity testing techniques. Faculty at CSU Fullerton and CSU Northridge have focused on the ichthyology of wetlands and embayments. Researchers at San Diego State University have performed studies of wetlands degradation and restoration and of the impacts of sewage from Mexico on the Tijuana estuary.

The California Institute of Technology (Cal Tech) supports the Environmental Engineering Program and the Environmental Quality Laboratory. Scientists in these two groups have been involved in the design of major wastewater outfalls in the bight and in developing design modifications for power plant cooling-water intakes that drastically reduced the numbers of fish taken in with the cooling water. In addition, Cal Tech scientists have studied the chemical and physical processes related to the movement and ultimate fates of discharged materials in the bight, have examined the chemistry of wastewater effluent, and investigated the fractionation of sewage sludge discharged to the ocean. For many years, Cal Tech also housed the Kelp Habitat Improvement Project, a long-term effort to understand the biology of kelp beds and enhance their survival and growth.

Notable among the research programs at small colleges in the bight is that at Occidental College, which has operated the R.V. *Vantuna* program for more than a decade. This ship-based program focuses on extensive otter trawling and diver ichthyological surveys, and on research on the effects of heated wastewater plumes from coastal power plants.

Private Industry

Private industries in the bight maintain research programs that are targeted at understanding the effects of specific discharges or other activities. With the exception of Southern California Edison's program, however, most of these are small and narrowly focused. Since 1972, the company has operated a research and development laboratory in Redondo Beach, and for many years supported a program of voluntary research termed the "Special Studies Program." These studies were carried out at SCE's initiative in order to:

- more clearly describe the effects of the company's permitted intake and discharge of power plant cooling water, and
- develop a greater understanding of the mechanisms underlying these effects.

Southern California Edison's research has included investigations of the effect of chlorinated discharges and thermal stress on various life stages of coastal fishes, fish behavior around cooling water intakes, the bightwide distribution patterns of ichthyoplankton and adult fishes, the biology of kelp beds, and remote sensing studies of surface-water temperature patterns throughout the bight. An unusual aspect of much of Edison's research is its emphasis on bightwide patterns and processes. For example, the company has attempted to determine whether its numerous coastal power plants, in the aggregate, have had any effect on larval and adult fish abundance and distribution in the bight. This orientation reflects the fact that Southern California Edison, unlike other dischargers, operates throughout the entire bight.

Research Successes

Research programs have contributed greatly to both the evolution of monitoring technology and to the mitigation of the impacts of human activity in the bight. These contributions are too numerous to list completely, but a few historical examples will indicate the breadth and importance of the relationship between research and monitoring programs in the bight.

For many years, scientists at USC's Allan Hancock Foundation carried out research on the biogeography of the bight. These studies described the fauna of the continental shelf and slope and the offshore basins. The resulting comprehension of zonation patterns was important in understanding the impacts of wastewater discharge. This information was also instrumental in determining the placement of outfalls and designing monitoring programs.

When Southern California Edison was first constructing coastal power plants in the bight, it worked closely with scientists and engineers at Cal Tech to redesign cooling water intakes to reduce the numbers of fish taken in with the cooling water (or impinged). Modeling and experimental studies showed that fish were disoriented by the vertical flow fields around intakes. As a result of this understanding, Southern California Edison fitted velocity caps to all intake structures. These velocity caps create a horizontal flow field around intakes, thus reducing the numbers of fish impinged by over 90 percent. Both the severity of the original problem and the efficacy of the velocity caps were documented by monitoring.

The diversion in 1971 of the County Sanitation Districts of Orange County's wastewater discharge from a shallow inshore outfall to a deeper outfall offshore provided a unique opportunity for research on both the recovery and disturbance of benthic communities. Gary Smith, of Scripps, studied the dynamics of community recovery at the old discharge site and the progress of disturbance effects at the new outfall site (Smith, 1974). The increased understanding of impact mechanisms that resulted from this study was extremely valuable in the continued improvement of monitoring around outfalls in the bight.

SUMMARY

Monitoring and research programs in the Southern California Bight are both diverse and intensive. They are carried out by a wide variety of federal, state, and local agencies, as well as by universities and private industry. Virtually every aspect of the marine environment is currently being monitored or otherwise investigated.

In many instances, research and monitoring activities have been closely coordinated, with research results being used effectively to improve and refine monitoring efforts. The active marine research community in Southern California has produced many innovations that have advanced the state of the art in marine monitoring. In addition, the large monitoring programs represent a valuable source of time-series data on the marine environment in the bight.

One of the most striking features of the monitoring and research system in the bight is the great number of programs carried out by an almost equally great number of agencies, universities, and industries. This has led to examples of interagency cooperation that could serve as a model for other regions facing similar problems. However, it has also led to fragmentation and a lack of integration, which has hampered monitoring efforts. These issues and others related to the technical design of monitoring programs will be dealt with in Chapters 5 and 6.

5
A Framework for the Analysis of Monitoring

The previous chapter documented the wide range of monitoring programs being carried out in the Southern California Bight. Because these programs can be evaluated from many different perspectives, it is important to clarify the criteria the panel used in its analysis of monitoring efforts. These criteria summarize the conceptual framework developed by the parent committee. They provide the basis for determining whether individual programs, as well as the monitoring system as a whole, are effective or not, and can be expressed as six questions:

1. Does monitoring address clearly stated management and societal objectives?
2. Does monitoring address the major environmental problems facing the bight?
3. Do the spatial and temporal scales of monitoring reflect those of the major environmental problems?
4. Are the technical design and implementation of monitoring of high quality? This includes proper statistical design of sampling and analysis, use of state-of-the art field and laboratory techniques, and adequate links to relevant research programs.
5. Do monitoring programs respond in a timely way to changing conditions and needs?
6. Are monitoring resources allocated effectively both within and among monitoring programs?

These criteria reflect the literature on monitoring (e.g., Holling, 1978;

Green, 1979; Beanlands and Duinker, 1983; Fritz et al., 1980, National Research Council, 1986; Isom, 1986; Rosenberg et al., 1981; and Bernstein and Zalinski, 1983, 1986) and the experience of the panel members.

It is important to recognize that issues addressed by the evaluation criteria are not strictly technical. This is because monitoring is defined by and carried out within a complex context that includes the interests and information needs of the public and the regulatory agencies and the requirements (procedural and otherwise) of relevant laws and permits, as well as strictly scientific and technical concerns. The analysis of monitoring must therefore look as much at the interface between policy and technical issues as at the technical issues themselves.

The following sections address three areas that are especially relevant to the analysis of monitoring and that underlie the evaluation criteria:

- the importance of clear objectives,
- the role of technical design and its statistical component, and
- the necessity for identifying, evaluating, and prioritizing environmental problems.

THE IMPORTANCE OF OBJECTIVES

Monitoring programs are intended to produce information for quantifying and evaluating the effects of human activity on the marine environment. Monitoring is intended to provide decision makers with the information they need to make appropriate management decisions about how to protect the marine environment and its resources. Ideally, these information needs should be expressed as objectives that guide the design and implementation of monitoring programs.

The objectives that currently motivate monitoring programs in the bight can be loosely structured as a hierarchy. At the highest level are broad concerns about human health and the status of the ecosystem. Beanlands and Duinker (1983) make the point that objectives at this level often reflect sociopolitical values that cannot always be quantified or supported scientifically. This, however, does not necessarily lessen their importance or relevance as the basis of management and monitoring efforts. At the next level are the laws and regulations that embody these concerns as more specific objectives or requirements. At the next level are permits for individual discharges or other activities, which in some cases contain numerical monitoring criteria. Finally, the monitoring design itself is based on decisions about what, specifically, to measure, when, where, and how often to measure it, and about what degree of uncertainty in the final answer is acceptable. Ideally, each level should incorporate the content and intent of the preceding level. Westman (1985) has described an analogous hierarchy in terms of successively more specific and detailed goals, policies, strategies, and tactics.

As the foregoing discussion implies, clear objectives are crucial for both the monitoring and decision-making aspects of environmental management. For monitoring practitioners, they direct monitoring efforts toward the measurement of specific parameters and of specific amounts and rates of change. Without such clear objectives, it is impossible to effectively use such technical design tools as conceptual, numerical, and statistical models, and power and optimization analyses. For managers and regulators, they provide a standard against which environmental change can be measured in order to determine if corrective action is required. It is therefore necessary to completely specify objectives at each level of the hierarchy, from broad public concerns to specific, numerical criteria.

THE ROLE OF TECHNICAL DESIGN

Technical design involves making decisions about what to monitor; how, when, and where to take measurements; and how to analyze and interpret the resulting data. The parent Committee on a Systems Assessment of Marine Environmental Monitoring developed a design methodology that the panel used to structure its evaluation of this aspect of monitoring in the Southern California Bight (Figures 5-1 to 5-4) (National Research Council, 1990). Figure 5-1 shows that technical design must be considered in relation to the initial definition of goals and objectives and the ultimate effective dissemination of monitoring information. Figures 5-2 to 5-4 provide additional detail about the relationships among specific elements of the methodology.

The methodology summarized in Figures 5-1 to 5-4 reflects definite concepts about effective monitoring design and its benefits. These concepts are not the only ones that could have been used to structure an evaluation of the technical design of monitoring programs. They do, however, reflect many of the important themes that recur in the literature on monitoring design. The following is a summary of these concepts:

• Appropriate technical design ensures that data collection, analysis, and interpretation will address management needs and objectives. oTechnical design can be performed adequately only when objectives, problems, questions, or hypotheses are stated explicitly.

• Sampling, measurement, and analysis designs should be developed with the goal of detecting specific kinds and amounts of change.

• Predictions about the kinds and amounts of change expected should be derived from conceptual models that specify how particular human activities (causes) will lead to environmental impacts (effects).

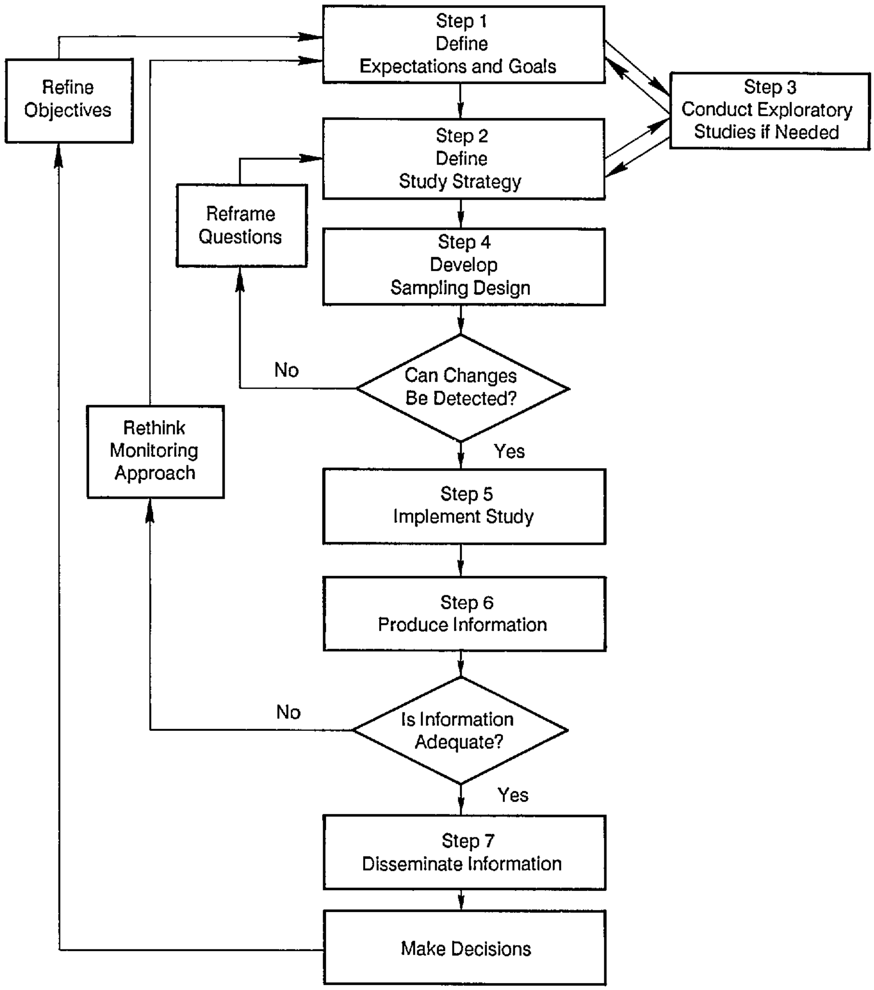

FIGURE 5-1 The elements of designing and implementing a monitoring program.

- Sampling and measurement designs should account for important sources of natural variability.
- Sampling and measurement designs should be evaluated beforehand to determine their ability to detect predicted changes.
- Analysis approaches should be selected before data collection to correspond to the statistical assumptions of the sampling design.
- Data base systems should make authorized versions of the data readily available to analysts and managers, and should provide easy access to a wide range of analysis, graphics, and reporting tools.

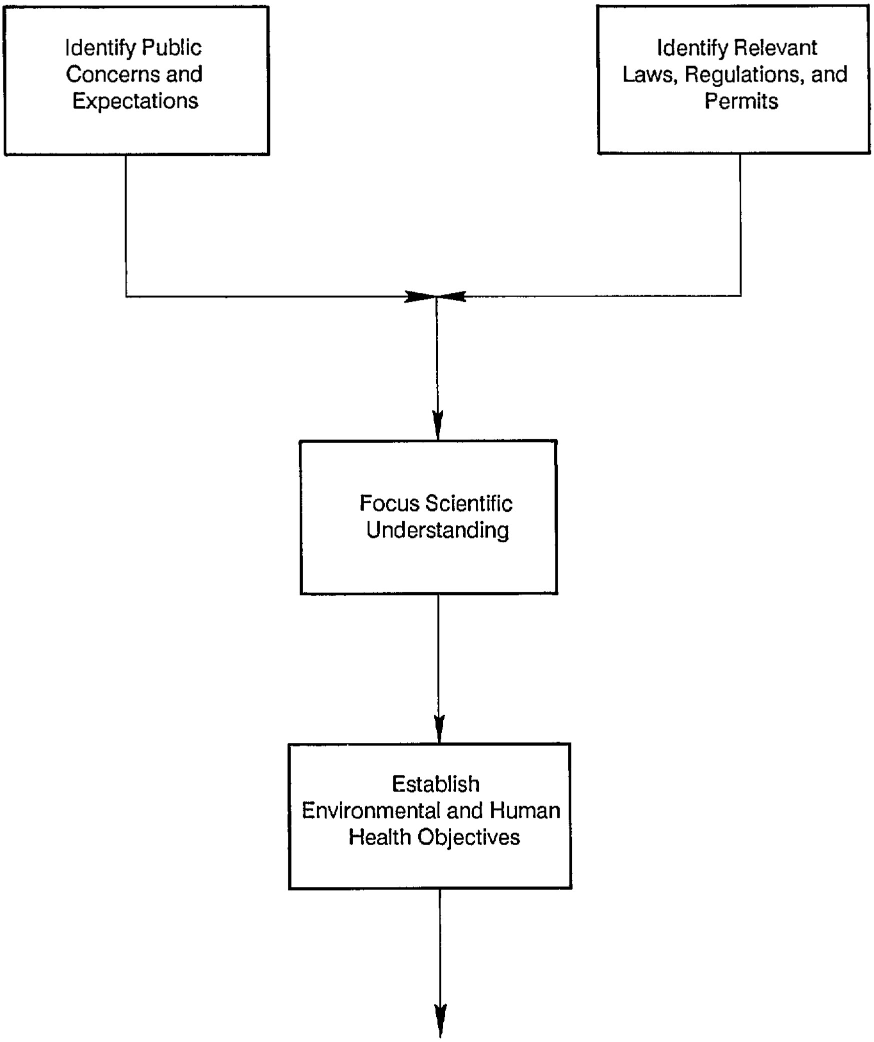

FIGURE 5-2 Step 1: Defining expectations and goals of monitoring.

The technical design process illustrated in Figures 5-1 to 5-4 furnishes a framework for translating broad questions and objectives into specific decisions about what to measure, where to measure it, and how many measurements to take. Using this framework as an evaluation tool enabled the panel to use a common set of standards in considering the technical design of monitoring programs in the bight.

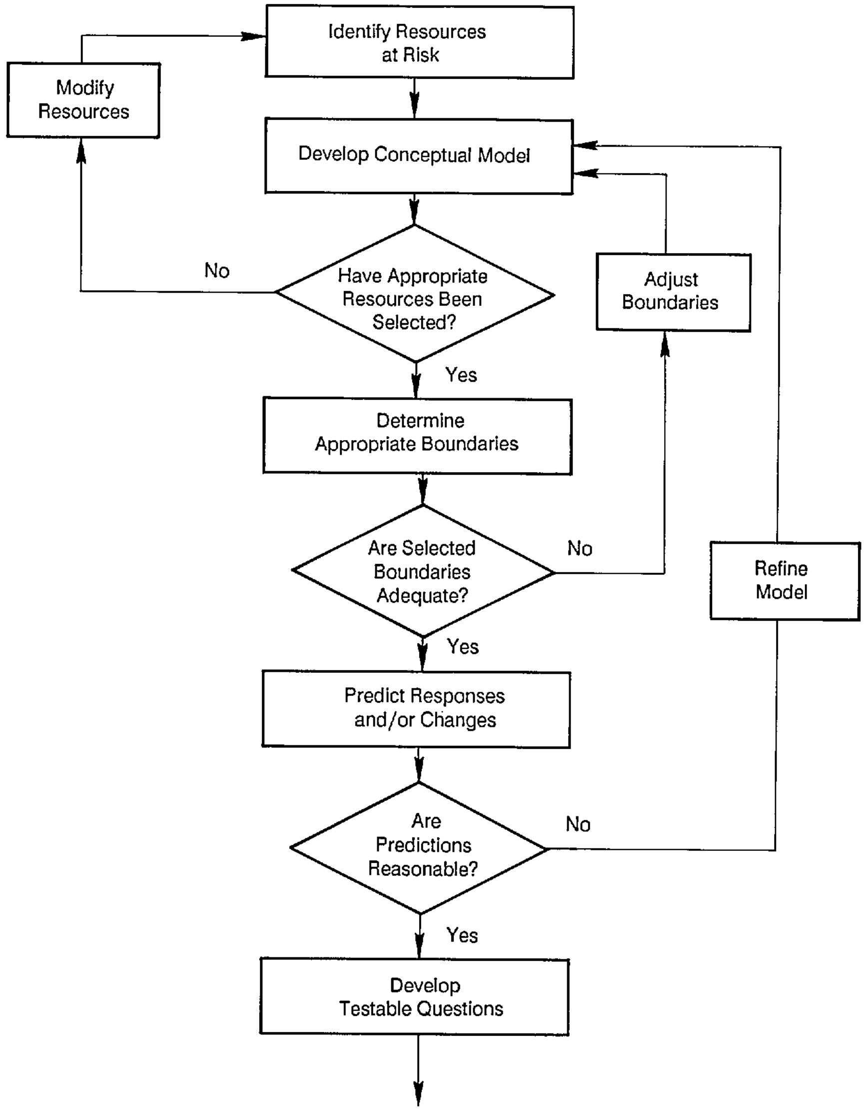

FIGURE 5-3 Step 2: Defining study strategy.

A FRAMEWORK FOR PRIORITIZING PROBLEMS

As stated previously, this case study is oriented toward examining the monitoring system in the bight as a whole. In addition to evaluating whether individual programs meet their objectives, this necessitates determining whether the entire collection of monitoring programs produces

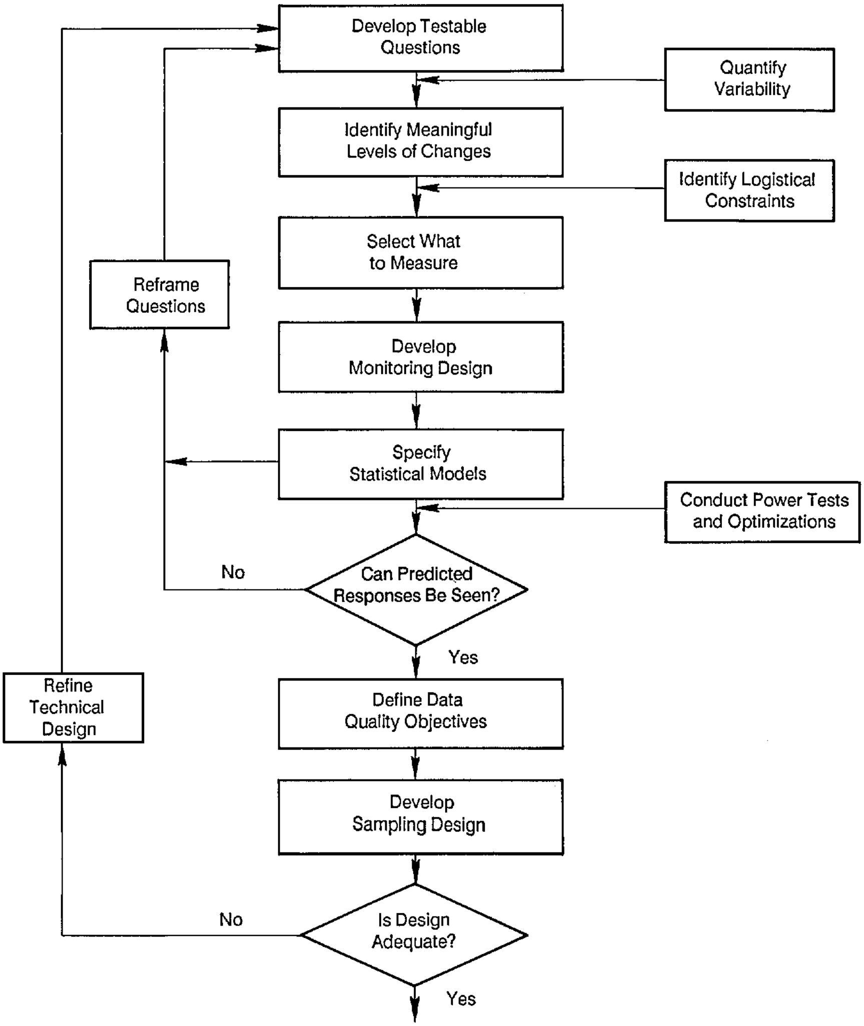

FIGURE 5-4 Step 3: Developing sampling and measurement design.

the information needed to satisfy both management and the public. The technical design methodology described above provided a means of structuring the analysis of individual programs. However, there was no similar framework available for the overall analysis of the monitoring system. The panel therefore adapted existing methods in order to perform a summary assessment of environmental impacts on resources in the bight. This assessment was intended to summarize the nature and severity of impacts on a range of important resources in the bight and was designed to help the panel address specific questions.

- Does monitoring address clearly stated management and societal objectives?
- Does monitoring address the major environmental problems facing the bight?
- Do the spatial and temporal scales of monitoring reflect those of the major environmental problems?
- Are monitoring resources allocated effectively both within and among monitoring programs?

The Assessment Framework

While many useful frameworks have been proposed for environmental assessments (see examples in Beanlands and Duinker, 1983; Westman, 1985; NRC, 1986), constructing one for monitoring in the bight in the context of the case study presented special difficulties. First, the goal of the assessment was to produce a synthetic overview that would aid in drawing conclusions about the entire monitoring system in the bight, both technical and institutional. This is in contrast to more typical assessments that focus only on identifying and quantifying the environmental impacts of individual projects. Second, the time available for developing this overview was necessarily short and the technical and financial resources available were limited. Third, there are extensive and diverse human and natural sources of perturbation in the bight and methods for characterizing multiple and cumulative impacts are not well developed. For example, effects on fish populations may derive from:

- coastal power plants–entrainment of larvae, impingement of adults;
- municipal wastewater outfalls–habitat alteration, changes in food supply, contamination;
- dredged material disposal–habitat alteration, contamination;
- storm runoff—contamination; and
- sport and commercial fishing–increased mortality.
- El Niños–changes in distribution and community structure, habitat alterations; and
- major storms–habitat alteration.

Such effects act on different spatial and temporal scales, and this adds to the challenge of understanding and portraying impacts.

To accommodate these constraints and difficulties, the panel used a combination of matrix and ad hoc assessment methods (Westman, 1985).[1]

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[1] The matrix approach was adapted from a framework developed by Clark (1986) for identifying

The assessment produced synoptic overviews that were useful in evaluating the overall pattern of monitoring in the bight. However, before reviewing the assessment products and explaining the supporting detail, it is important to understand the limitations of the matrix and ad hoc methods used. In most cases, the limitations of each method were somewhat balanced by the strengths of the other. The procedure described by Clark (1986) proceeds through a series of steps that specify:

- valued ecosystem components (VECs),
- marine constituents (both natural ecosystem parameters and anthropogenic contaminants) that cause changes in the VECs, and
- sources of natural and human-induced perturbation that create or cause changes in these constituents, which are linked in a matrix with specific VECs to show how they—along with contamination in the bight—affect marine resources (Figure 5-5).

The selection of perturbations, constituents, and VECs is necessarily somewhat arbitrary. Given the size of the bight and the multiplicity of resources and sources of impact, some selection among these was unavoidable. This selection reflects the values and biases of the panel, but the critical reviews by experts and scientists outside the panel were designed to balance competing points of view. However, there is no denying that other reviewers might have generated parameters that would have led to a different assessment.

The matrices do not specifically identify primary, secondary, and higher order interactions among perturbations, constituents, and VECs. This would be a severe shortcoming if the matrices were used as a stand-alone assessment method. In this case, however, the matrices were used as a cross check for the conclusions derived from the ad hoc approach and to enforce a degree of systematic thinking. While the matrices themselves do not specify interactions, they were discussed at length during preparation of the matrices and as part of the ad hoc approach.

The matrix products do not quantify effects and impacts. Rather Figure 5-5 scales two impact attributes, the potential influence of each source of perturbation and the degree of scientific certainty associated with this conclusion. This is similar to the scaling of impact magnitude and importance proposed by Leopold et al. (1971) in a similar matrix. This subjective scaling would be a major shortcoming if the panel's intent was to perform a damage assessment, a detailed project assessment, or a comparison of two or more alternative development scenarios. However, in

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cumulative impacts. The ad hoc portion of the assessment (Rau and Wooten, 1980) consisted of brainstorming sessions with experts and critical review of the matrix products by individual scientists. The matrix products were modified a number of times to incorporate feedback from brainstorming sessions and individuals' reviews.

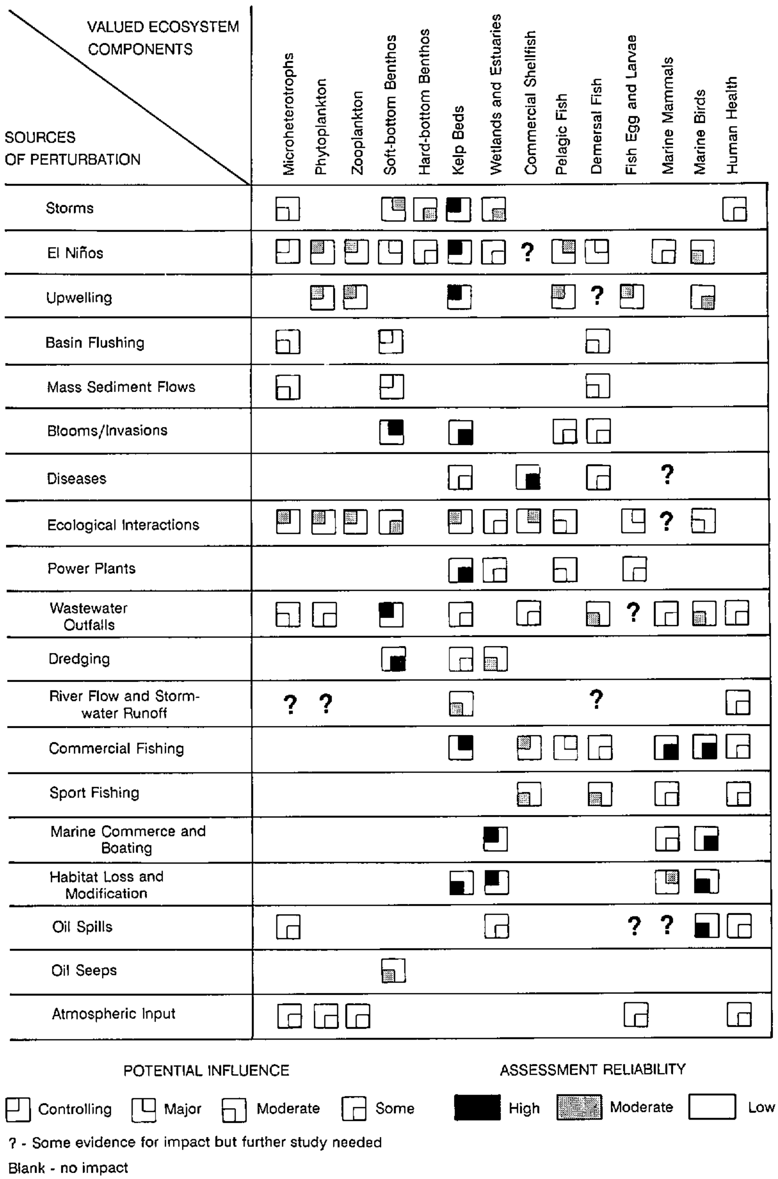


FIGURE 5-5 Impacts on the marine environment of the Southern California Bight. Individual cells of the matrix illustrate the presumed relative impact of each source on each component, along with the associated scientific certainty. Each column represents cumulative impacts on individual components; each row shows the effects of individual perturbations on all components. This figure was used to summarize and investigate ways of identifying and ranking impacts in the bight. SOURCE: After Clark, 1986.

this case the panel's goal was to produce a high-level overview that would assist in comparing the overall pattern of impacts with the overall pattern and structure of monitoring programs. In addition, much of the background information used in both the matrix and ad hoc efforts was derived from extensive and quantitative research, monitoring, and modeling programs.

The overviews that resulted from the assessment lack detail about the nature of the effects they represent. Again, this is less of a problem given the panel's task. In fact, the high-level, summary character of the overviews was actually helpful in elucidating the weaknesses of the existing monitoring structure.

The ad hoc method depends on the collected experience and insights of the participants. As a result, conclusions are dependent not only on the selection of participants but also on their values and biases. Under the circumstances, the panel believed that enlisting the participation of a cross section of scientists from the bight region was the most efficient means of integrating the wealth of scientific and technical information available. Involving scientists of differing affiliations helped to balance individual values and biases. In addition, the matrix method helped to focus, systematize, and cross check each person's opinions and judgments.

No assessment method is perfectly objective. While quantitative models are increasingly valuable, even they depend on certain simplifying assumptions and often are challenged. Similarly, even a moderately sized monitoring program must make judgments about which aspects of the environment to measure or ignore, since it is impossible to measure everything. The panel used the assessment products to derive conclusions about the structure and focus of the monitoring system in the bight. The conclusions were judged to be robust enough to form the basis for conclusions and recommendations, even in light of the acknowledged limitations of the assessment methods used.

A Synoptic Overview

The matrix in Figure 5-5 is a useful heuristic tool. It shows that all ecosystem components are impacted by more than one kind of perturbation. It also shows that perturbations typically affect more than one ecosystem component. For example, storms affect soft benthos, kelp beds, and human health; wastewater outfalls affect soft benthos, microheterotrophs, and demersal fish populations.

Figure 5-5 helps categorize the types of monitoring programs in the bight. Some programs examine the effects of one perturbation on a single resource. These programs focus on one cell of Figure 5-5 and are called single-cell assessments. For example, the impingement sampling program carried out by the Southern California Edison Company is intended to assess the potential impacts of coastal power plants on pelagic fish populations. Other monitoring programs examine the effects of one perturbation on a range of resources. These programs focus on an entire row of Figure 5-5 and are called row assessments. For example, the 301(h) monitoring program around the Orange County wastewater outfall is designed to document the effects of the outfall on a range of resources, including soft benthos, water quality, and demersal fish populations. Monitoring programs that consider how several perturbations, acting together, affect a single resource would focus on an entire column of Figure 5-5 and are called column assessments. There are no examples of such programs in the bight, a fact which will be addressed in more detail in Chapter 6. Further, there are no coordinated monitoring programs in the bight that focus on the effects of two or more sources of perturbation on a range of related resources. Such a program, for example, might document the combined effects of fishing, power plants, and wastewater outfalls on demersal and pelagic fish populations.

Figure 5-5 also presents subjective judgments about the relative importance and degree of scientific certainty associated with each impact. For example, wastewater outfall impacts on soft benthos are more severe and extensive than those from dredging. As another example, it also shows that conclusions about kelp bed impacts are probably more reliable than those about effects on fish eggs and larvae. Such comparisons aid in analyzing existing monitoring programs by suggesting where further research would be more appropriate and useful than routine monitoring. As Chapter 6 makes clear, available financial and technical resources in the bight are not systematically allocated to research and monitoring on the basis of a comprehensive overview like the one in Figure 5-5.

As with Figure 5-5, Figure 5-6 is a useful heuristic tool that supplies insights about the structure of existing monitoring programs in the bight. It shows quite clearly that the impacts that are relatively well understood (e.g., coastal power plant plumes, disposal of coarse dredged material, nutrients, fine particles) are those whose scales are either less than or of the same order of magnitude as those of monitoring programs. It also demonstrates that, with the exception of the CalCOFI program, the temporal and spatial scales of individual monitoring programs are insufficient to resolve patterns of effects on larger scales. While the effects of scale are becoming a matter of concern to ecologists (Wiens, 1989), Figure 5-6 demonstrates that monitoring programs in the bight are not consistently designed with such scale effects in mind. As Wiens (1989) points out, these effects can be complex, and—if not considered carefully—". . . we may think we understand the system when we have not even observed it correctly."

Supporting Detail

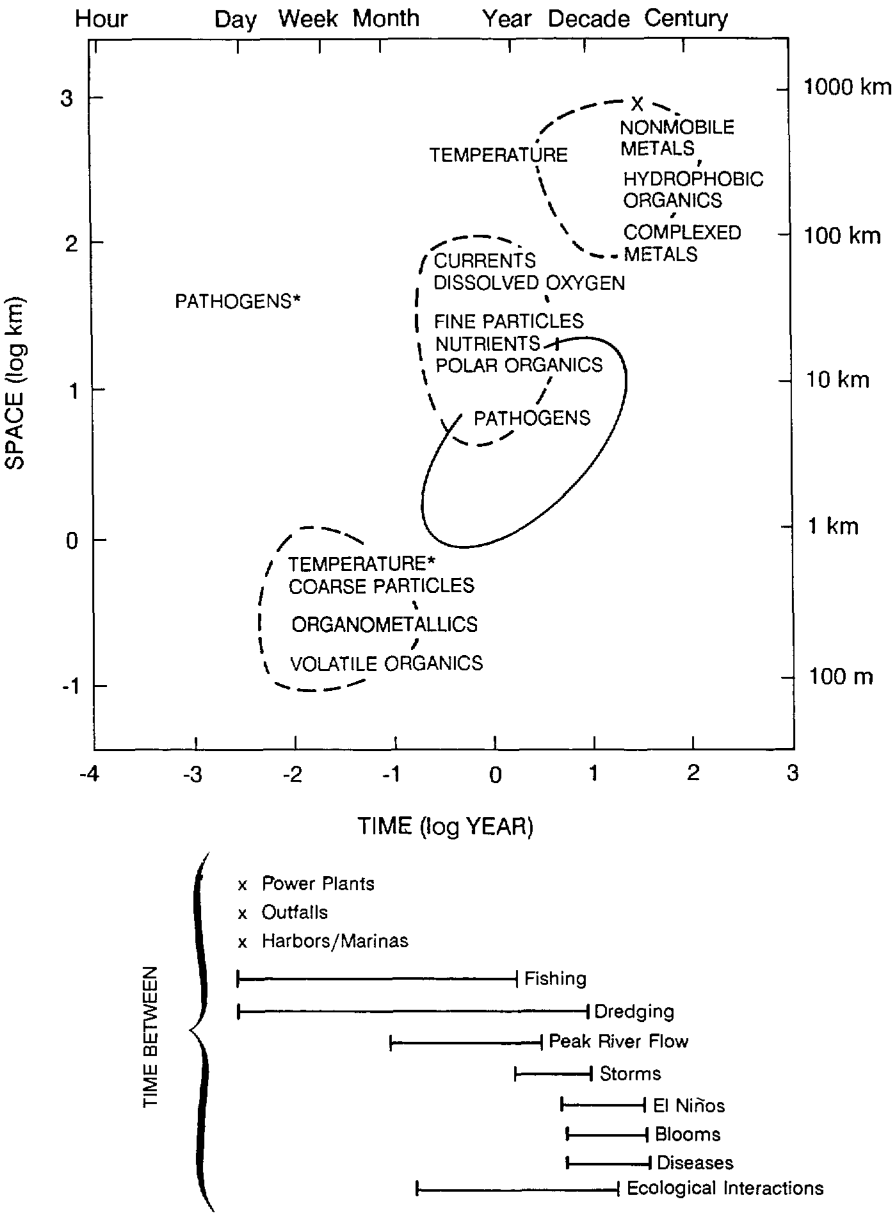
As the first step in the matrix assessment procedure, the effects of the constituents on the VECs are identified (Figure 5-7), and the ways in which sources of perturbation cause changes in these constituents are then specified (Figure 5-8). This permits sources of perturbation to be linked (through changes in the constituents) directly to effects on VECs in a matrix (Figure 5-5). This in turn allowed the panel to summarize the effects of various human and natural processes on the VECs. Finally, the temporal and spatial scales of constituents and perturbations (Figure 5-6) are compared to the spatial and temporal scales of relevant monitoring programs.

Figure 5-7 qualitatively shows the effects of changes in marine constituents on valued marine ecosystem components. VECs include important ecosystem components and major fisheries, as well as demersal and pelagic fish life stages that occupy distinct habitats and might be affected differentially. Constituents are divided into physical oceanographic parameters (e.g., waves or temperature), and into floating, dissolved, suspended, and settleable categories. Figure 5-7 shows that specific constituents impact more than one VEC and that some VECs are affected by more than one constituent.

The constituents shown in Figure 5-7 were selected because they are typically measured in monitoring programs. Their division into floating, dissolved, suspended, and settleable categories reflects the fact that their association with particles of different sizes significantly influences the fates and effects of most contaminants. However, the selection and arrangement of these constituents is certainly not the only one possible. For example, rather than focusing on physical and chemical parameters, the constituents could include important dynamic processes, such as production, nutrient regeneration, the flux of organic matter, and recruitment and mortality.

Figure 5-8 furnishes the next link in the matrix-based assessment by showing which sources of perturbation affect which constituents. This then permits connecting sources of perturbation to effects on VECs. For example, the amount and distribution of fine particles and nutrients are affected by wastewater outfalls (Figure 5-8), and such changes can potentially affect the soft benthos (Figure 5-7). This suggests a potential mechanistic link between wastewater outfalls and effects on the soft benthos. Similarly, marine commerce and boating create floating debris (Figure 5-8), which affects marine birds (Figure 5-7). (These admittedly simplistic examples were chosen for illustrative purposes; the reader is encouraged to investigate other links suggested by Figures 5-7 and 5-8).

These two figures can be integrated to furnish a synoptic view of the impacts of both natural and human perturbations on the VECs. Thus, one


Hour
Day
Week
Month
Year
Decade
Century
3
2
1
0
-1
SPACE (log km)
1000 km
100 km
10 km
1 km
100 m
X
NONMOBILE METALS
TEMPERATURE
HYDROPHOBIC ORGANICS
COMPLEXED METALS
CURRENTS
DISSOLVED OXYGEN
PATHOGENS*
FINE PARTICLES
NUTRIENTS
POLAR ORGANICS
PATHOGENS
TEMPERATURE*
COARSE PARTICLES
ORGANOMETALLICS
VOLATILE ORGANICS
-4
-3
-2
-1
0
1
2
3
TIME (log YEAR)
TIME BETWEEN
x Power Plants
x Outfalls
x Harbors/Marinas
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Storms
El Niños
Blooms
Diseases
Ecological Interactions

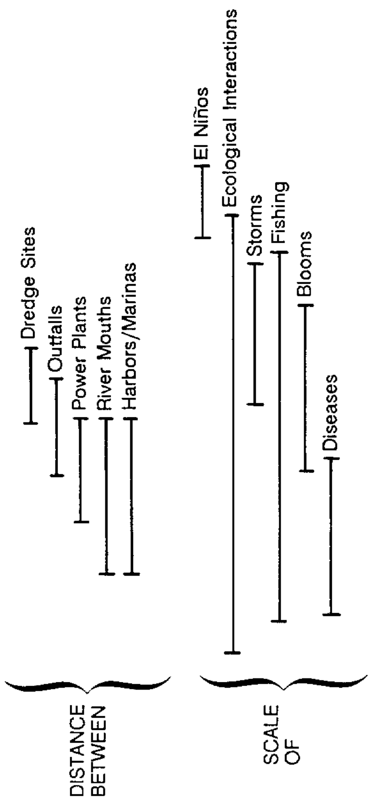

FIGURE 5-6 Characteristic temporal and spatial scales of important constituents and sources of perturbation. Constituents are the same as those in Figure 5-6, but have been abbreviated. "Temp *" refers to temperature changes from coastal power plants, and "Temp" to natural temperature changes (i.e., El Niño events). "Path *" refers to bacterial contamination from wastewater outfalls and storm runoff, and "Path" to pathogens from natural sources that cause diseases in urchins, fish, and other organisms. The abscissa represents a crude estimate of the half life or recurrence time of each constituent. The ordinate represents the spatial displacement likely to occur over that time, or the scale of activity. For example, nonmobile metals and hydrophobic organics are presumed to persist in the environment and spread much more widely than nutrients. The temporal and spatial boundaries of existing monitoring programs are outlined by a solid line, with the exception of the CalCOFI Program, whose parameters are indicated by an "X" in the upper right of the figure. Constituents with similar temporal and spatial scales are outlined with dotted lines. SOURCE: After Clark, 1986.

MARINE CONSTITUENTS \ VALUED ECOSYSTEM COMPONENTS	Microheterotrophs	Phytoplankton	Zooplankton	Soft-bottom Benthos	Hard-bottom Benthos	Kelp Beds	Wetlands and Estuaries	Commercial Shellfish	Pelagic Fish	Demersal Fish	Fish Eggs and Larvae	Marine Mammals	Marine Birds	Human Health
OCEANOGRAPHIC														
Currents		●	●								●			
Winds		●	●								●			
Waves				●	●	●	●							
Temperature	●	●	●	●	●	●	●		●	●	●			
Dissolved Oxygen	●			●	●		●	●		●	●			
FLOATING														
Floating Debris												●	●	●
DISSOLVED														
Nutrients	●	●		●	●	●			●	●	●	●	●	
Volatile Organics	●	●									●			
Polar Organics	●	●	●								●			
Complexed Metals			●											
Organometallics			●											
SUSPENDED														
Fine Particles		●				●		●						
Coarse Particles					●	●		●						
Nutrients								●			●			
Pathogens						●		●		●		●	●	●
Hydrophobic Organics			●				●	●	●	●		●	●	●
Organometallics			●				●	●		●		●	●	
Nonmobile Metals							●							
SETTLEABLE														
Fine Particles				●	●		●							
Coarse Particles				●	●	●	●							
Nutrients				●	●					●				
Hydrophobic Organics				●	●		●							
Nonmobile Metals				●	●		●							

FIGURE 5-7 Major impacts of natural features of the ecosystem and anthropogenic contaminants on valued ecosystem components. The dots indicate that the listed constituent (left) is presumed to have a significant impact on that ecosystem component (top). Both direct and indirect impacts are included. Volatile organics include phenols and halomethanes; polar organics, PAH, DDT, and PCB. Nonmobile metals include lead and cadmium; complex metals—nickel and copper; organometallics—mercury, tin, selenium, and arsenic. Nutrients include both dissolved nutrients and nutrients associated with particles. Pathogens include those from both anthropogenic (e.g., coliforms) and natural (e.g., urchin disease) sources. Dissolved constituents are those less than .04 μm in size. Settleable constituents are defined operationally as those that settle to the bottom as a function of size and specific gravity. Valued ecosystem components include various parts of the food chain, communities associated with specific habitats (e.g., kelp beds), and important fisheries. Commercial shellfish include abalones, lobsters, and urchins. SOURCE: After Clark, 1986.

can start with VECs such as soft benthos or demersal fish populations, identify the constituents that affect them, and then trace these constituents back through their relationships with sources of perturbation to finally determine all the kinds of perturbations that affect these ecosystem components. The result of this process can be displayed as a matrix (Figure 5-5) that summarizes the impact of each kind of perturbation on each ecosystem component.

Figure 5-5 was constructed using other knowledge from the ad hoc method in addition to the mechanistic linkages shown in Figures 5-7 and 5-8. This points up shortcomings in the selection and organization of the constituents shown in Figure 5-7. For example, Figure 5-5 shows that sport and commercial fishing impact pelagic and demersal fish by directly removing individuals from the population. However, since Figure 5-8 does not include mortality as one of the marine constituents, Figures 5-7 and 5-8 do not combine to predict impacts on fish from fishing, an obvious failing. In addition, Figure 5-5 indicates that blooms, natural diseases, and especially ecological interactions have significant effects on the VECs. However, Figure 5-7 shows that none of these important sources of perturbation interact strongly with any of the constituents other than temperature and dissolved oxygen. The panel thus combined insights from both the matrix and ad hoc methods without rigidly adhering to the limitations of either.

Figure 5-5 is an informative way to organize existing knowledge about impacts on marine resources. However, the spatial and temporal scales of both perturbations and ecosystem processes vary widely and this information is necessary to evaluate the effectiveness of monitoring. The overall assessment framework therefore includes a means of organizing and comparing the temporal and spatial scales of constituents and perturbations. A preliminary approach is presented in Figure 5-6. The constituents are placed in a logarithmic time-space coordinate system based on crude estimates of their half-lives in the marine environment (for contaminants) or their typical scale of activity (for ecosystem features). The temporal and spatial range of existing monitoring programs is indicated, and the temporal and spatial scales of important perturbations shown along the x and y axes, respectively.

SUMMARY

This chapter presents the criteria and concepts used to organize the analysis of monitoring efforts reviewed in the next chapter. Six key questions made up the evaluation criteria used to assess both individual monitoring programs and the collection of monitoring programs in the bight. These questions addressed both the policy and technical aspects of monitoring,

MARINE CONSTITUENTS \ SOURCES OF PERTURBATION	Storms	El Niños	Upwelling	Basin Flushing	Mass Sediment Flows	Blooms/Invasions	Diseases	Ecological Interactions	Power Plants	Wastewater Outfalls	Dredging	River Flow and Runoff	Commercial Fishing	Sport Fishing	Marine Commerce and Boating	Habitat Loss and Modification	Oil Spills	Oil Seeps	Atmospheric Input
OCEANOGRAPHIC																			
Currents		●	●													●			
Winds	●															●			
Waves	●															●			
Temperature		●	●	●		●	●	●	●										
Dissolved Oxygen		●	●	●				●	●										
FLOATING																			
Floating Debris										●		●	●	●	●				
DISSOLVED																			
Nutrients	●	●	●	●	●					●		●							●
Volatile Organics										●		●			●		●		
Polar Organics										●		●			●		●		
Complexed Metals									●	●		●			●		●		●
Organometallics									●	●		●			●		●		
SUSPENDED																			
Fine Particles	●			●						●	●	●							
Coarse Particles	●								●	●	●	●							
Nutrients	●									●		●				●			
Pathogens																			
Hydrophobic Organics										●	●	●							
Organometallics									●	●	●	●							
Nonmobile Metals									●	●	●	●							●
SETTLEABLE																			
Fine Particles	●				●				●	●	●	●				●			
Coarse Particles	●				●				●	●	●	●				●			
Nutrients	●				●					●		●				●			
Hydrophobic Organics					●					●	●	●							
Nonmobile Metals					●				●	●	●	●							

FIGURE 5-8 Sources of major perturbations to the bight's marine ecosystem and their major impacts on marine constituents. The dots indicate that the listed perturbation (top) is presumed to have a significant effect on the listed constituent (left). Both direct and indirect impacts are included. Perturbations include both human and natural sources of change. Basin flushing refers to the turnover of near-bottom water in offshore basins; mass sediment flows to sudden, large movements of sediment on the shelf; blooms or invasions to rapid increases in population levels of otherwise rare species (e.g., the echiuran *Listriolobus* or the kelp isopod *Pentidothea resecta*). Multiple sources of impacts of one kind (e.g., power plants, dredging) have been lumped to provide a consistent level of generality among perturbations. SOURCE: After Clark, 1986.

emphasizing the panel's focus on the functioning of the monitoring system as a whole.

Three areas that are especially relevant to the evaluation criteria were also discussed. Clear objectives are crucial in providing direction for monitoring design and implementation. An effective technical design then translates these objectives into decisions about what to monitor; how, when, and where to take measurements; and how to analyze and interpret the data. Finally, an overall assessment of environmental problems in the bight provides a framework for determining if all important questions are being addressed and whether monitoring resources are being allocated effectively.

6
Analysis of Monitoring Efforts

As described in Chapter 4, there exists a wide range of current and historical monitoring efforts in the Southern California Bight. Analyzing each of these in turn would be an unrealistic task, but examining only a few in detail might cause us to neglect important insights and patterns that could be derived from a broad survey. This review therefore identifies important conceptual issues, and illustrates them using examples from existing monitoring programs.

Many of these issues and examples identify shortcomings of the monitoring system and existing programs, and others stress positive developments. The analysis that follows emphasizes that monitoring efforts in Southern California are characterized by a commitment to technical excellence and continued evolution toward more sophisticated and effective planning and implementation. There is a broad consensus in the monitoring community that programs today are, in general, vastly improved over those in effect 10 or more years ago. This progress has highlighted remaining problems and has allowed attention to shift to broader concerns. The willing participation in this case study by all parts of the monitoring community is clear evidence of their interest in continuing to improve monitoring efforts.

This chapter focuses on four main topics:

1. institutional objectives and their limitations,
2. technical design and implementation,
3. technical interpretation and decision making, and

4. the overall allocation and organization of monitoring.

Judgments about monitoring's effectiveness in each of these areas are based on the criteria and concepts outlined in Chapter 5. This chapter discusses these concepts more extensively, in light of evidence from specific programs.

The panel's analysis of monitoring was based in large part on the written and verbal comments of invited speakers at the fact-finding sessions and further in-depth interviews with members of the monitoring community. The specific comments of these participants in the case study contributed to a consensus about the overall strengths and weaknesses of monitoring in the bight. This consensus is presented here as a series of statements and is amplified in the following sections.

The strengths of the monitoring system include:

- an established legal requirement for addressing environmental issues and problems;
- important contributions to environmental decision making;
- active links to ongoing research programs;
- innovative monitoring program designs and techniques;
- high-quality methods for collecting, analyzing, and interpreting data;
- raw monitoring data of high quality and integrity;
- large data sets that have greatly increased understanding of localized impacts, particularly of municipal wastewater discharges; and
- a few long-term data sets that are valuable for examining large-scale and long-term effects of human activities on the bight.

The weaknesses of the monitoring system include:

- poorly defined management objectives;
- poorly defined monitoring endpoints or decision criteria, especially for narrative water quality objectives;
- lack of explicit conceptual designs that link monitoring to specific hypotheses or paradigms about the ocean environment;
- inability to address regional or cumulative effects in the bight as a whole;
- sampling designs that do not take into account spatial and temporal scales of natural variability;
- reliance on a shotgun approach that measures many parameters, regardless of their relevance to operational, environmental, or public health decisions;
- rigidity that does not permit dropping redundant or outdated parameters, incorporating research with defined endpoints, or making adjustments in the light of new information;

- over-commitment of resources to well-understood problems;
- lack of a data management system containing a wide range of data types from all major monitoring programs;
- absence of synthesis that provides usable information to managers and other decision makers; and
- inability to effectively report the overall status of the resources and water quality in the bight to the public, the scientific community, and policy makers.

It should be emphasized that this consensus reflects the judgment of many people actively involved in designing, carrying out, and using the data from monitoring programs. Thus, in spite of the strengths mentioned above, and the fact that monitoring data have been used in decision making, there is evidence that the monitoring system could be more efficient, focused, and comprehensive.

INSTITUTIONAL OBJECTIVES AND THEIR LIMITATIONS

As described in Chapter 5, the objectives that motivate marine monitoring can be considered as a hierarchy or continuum. This begins with broad public concerns about public health and the status of marine resources; extends through laws, regulations, and permits; and ends with the specifications of individual monitoring programs. In Chapter 3 the public's concerns were reviewed in the section "Public Concerns for the Bight," while the laws that furnish the regulatory context for monitoring were reviewed in "The Regulatory Sector." Finally, the structure of effluent limitations and water quality criteria was described in Chapter 4 in "The Monitoring Sector."

These objectives influence the design of monitoring programs. They also influence the institutions that oversee the monitoring system. As a result, objectives are expressed explicitly in permits and other documents and implicitly in the behavior of the institutions that regulate monitoring. The following two sections address each of these aspects in turn.

Objectives

Because of the vast number of parameters that could be measured in the marine environment, monitoring programs require clear and precise objectives. The numeric effluent limitations and water quality criteria in discharge and other permits provide such precision. However, the narrative water quality criteria relating to unacceptable degradation or change do not furnish this level of precision. For example, the NPDES permit for the County Sanitation Districts of Orange County states that marine communities shall not be degraded. To monitor degradation in fish communities, a program could legitimately focus on any of the following parameters:

- diversity,
- species richness,
- community trophic structure,
- relative abundance of numerically dominant species,
- population sizes of numerically dominant species,
- population sizes of trophically important species,
- size-age relationships,
- reproductive potential as measured by gonad weight,
- mortality of one or more species,
- incidence of fin rot, tumors, and other abnormalities, or
- body burdens of specific contaminants.

Although these are all measurable parameters that may be indicators of degradation, they do not define it. To design a monitoring program with the objective of ascertaining "degradation," the term must be defined in a meaningful way. Thus, monitoring program objectives should be stated as clear, preferably quantitative, questions or null hypotheses: for example, a program could be designed to determine if the three most abundant fish species within 3 mi of the Orange County outfall had decreased in abundance by more than 50 percent from one year to the next. Such a decrease might be defined as a degradation of these fish populations.

One of the most comprehensive efforts to state monitoring objectives in Southern California is an Environmental Protection Agency (EPA) document titled *Objectives and Rationale for the County Sanitation Districts of Orange County 301(h) Monitoring Program.* For each program element, objectives of the relevant laws and regulations are stated, and sampling and analysis plans are specified. Objectives are precisely stated for influent, source control, effluent, and solids-handling monitoring. Although objectives for receiving-water monitoring are stated more clearly than ever before, they still contain no quantitative criteria for the kinds or amounts of change that should be monitored for. This is an important shortcoming because receiving-water monitoring focuses directly on determining whether human and ecosystem health objectives are being met.

This demonstrates that another level of detail is needed if monitoring in the bight is to consistently provide useful information. It should consist of specific descriptions of the kinds of changes, along with quantitative criteria about the amount of change, that should be monitored for. Hypothetical examples of such objectives, framed as null hypotheses, might be as follows:

- The operation of diffusers for the discharge of cooling water will not decrease the monthly average light transmission in the upcoast quarter of the adjacent kelp bed more than X percent below light transmission in the downcoast quarter of the kelp bed.

- The area around the sewage outfall outside the zone of initial dilution (ZID) exhibiting a change in benthic diversity of X percent or more shall not increase from year to year. Background diversity shall be defined as that found at reference stations A, B, and C.
- The long-term trend of DDT in the muscle tissue of adult Dover sole from the Palos Verdes Shelf shall not increase. Long-term shall mean a period of five years or more, and sampling shall be designed to detect a change in the long-term average of at least 5 percent.

These null hypotheses define a specific parameter and the amount of change to be measured. Before actual sampling begins, additional detail relating to confidence limits, background levels, and other factors must be decided. In the first hypothesis above, locations (surface, bottom, midwater, water column average), time scales (daily, weekly, monthly averages), and distribution of sampling stations must all be established. These decisions can be made with the support of the technical design tools outlined in Figures 5-1 to 5-4. In contrast to most objectives used as the basis of receiving-water monitoring, the three examples above provide the foundation for focused, efficient monitoring programs.

In contrast to other major monitoring programs in the bight, the Marine Review Committee (MRC) programs around the San Onofre Nuclear Generating Station (SONGS) were all designed with a specified probability of detecting definite amounts of change (Chapter 5). This policy was based on predictions of impacts and on a management decision that these amounts of change would be accepted as evidence of power plant impact.

There are two impediments to establishing this detailed level of objectives: (1) incomplete scientific knowledge (for example, an inability to establish source/receptor relationships), and (2) the institutional environment of monitoring. The environmental effects of all human activities cannot be predicted accurately. Where they cannot, objectives must necessarily remain more subjective, or research should be performed. In other cases, however, environmental effects are well enough understood that reasonably accurate predictions could be used to design more efficient monitoring programs. The changes that occur in the benthos around municipal waste discharges are a case in point. Changes in community composition, abundance, diversity, etc., have been well documented and could be used to develop more ecologically relevant and precise receiving-water objectives. Even where clearer and more quantitative objectives could be developed, however, there may be institutional constraints against implementing them.

For example, quantitative receiving water objectives could decrease regulatory flexibility if they were rigidly interpreted as a measure of compliance and automatically triggered management actions or litigation.

Despite these impediments, clearer monitoring objectives would result in beneficial gains in clarity, efficiency, and useful information. These gains would make the effort involved in developing them and integrating them into the regulatory framework worthwhile. In spite of these benefits, a danger of quantitative monitoring objectives is that they may be applied blindly, with little regard for naturally occurring effects. For example, between 1973 and 1977, there was a massive influx of the echiuran worm *Listriolobus* into benthic communities in the bight (Stull et al., 1986). This organism's burrowing, respiratory, and feeding activities aerated and reworked sediments throughout the bight. In areas of wastewater impacts (particularly White Point on the Palos Verdes Shelf) these activities reduced apparent impacts from the Los Angeles County outfall. When the worm disappeared, impacts reappeared. Without awareness of this naturally occurring but anomalous and confounding event, the strict application of quantitative criteria would have led to the erroneous conclusion that impacts of wastewater outfalls had decreased and then increased.

Institutional Limitations

The statutory and regulatory framework within which monitoring is conducted in Southern California has evolved piecemeal over time, and as a result, deficiencies and inconsistencies exist within the institutional structure. These affect not only the way monitoring is carried out but also the quality of the information monitoring can produce. The most important of these limitations are:

- lack of attention to nonpermit activities that may have large environmental impacts;
- rigidity and lack of flexibility; and
- a piecemeal, permit-by-permit approach to problems that may actually be larger in scope.

These limitations will be discussed in turn and illustrated with specific examples.

Nonpermit Activities

The vast majority of monitoring in the bight is compliance monitoring; that is, it is required as a condition of obtaining a permit. The unstated assumption underlying this policy is that the permitting process addresses all aspects of discharges and other activities that potentially affect the environment. This is not always the case, however, since some large inputs of contaminants are not covered by permits. These include rivers, which contain runoff, treated municipal waste water, and upstream discharges; storm drains; fallout of airborne pollutants; and diffuse inputs of hydrocarbons and other contaminants from marinas and harbors.

Although rainfall is sporadic in Southern California, winter storms can dump 1 to 3 or more inches of rainfall within 24 hours, washing accumulated contaminants from streets, sidewalks, and other surfaces into rivers and storm drains, where they are carried out to the ocean. The river system in the Los Angeles basin (Figure 1-2) drains a watershed of over 4,100 mi^2. During a major storm, the Los Angeles River alone can discharge 65 billion gal of water during a 24-hour period. Additional runoff enters the ocean directly from storm drains. For example, 75 separate storm drains discharge into Mission Bay in San Diego. Many of the industries that discharge into rivers and storm drains operate under National Pollutant Discharge System (NPDES) permits, and there is some monitoring in the Los Angeles basin rivers. However, many river and storm drain inputs are not monitored, and the system as a whole is not managed as a source of contamination.

The bight is adjacent to urban areas that are major sources of air pollutants. Aerial fallout to the ocean surface constitutes a significant source of contaminants (e.g., Table 2-2). The many marinas and harbors are sources of hydrocarbons and other contaminants derived from bilge pumping, sewage discharge, fuel loading and transfer, marine construction and maintenance activities, and ship traffic. Therefore, it is clear that monitoring to satisfy permit requirements does not address all of the large inputs of pollutants to the bight.

Inflexibility

Because monitoring programs are typically defined in regulatory permits, it is difficult to alter them as knowledge accumulates. The lengthy public hearing process required for updating permits has occasionally deterred permittees from attempting to modify their monitoring programs. In addition, there is a natural reluctance to discard or modify parameters that have traditionally been measured, but which may now be outmoded. As a result, monitoring programs often include outdated or inappropriate measurements. Further, procedures that are experimental or in development have been incorporated as routine elements of monitoring, even though the data they produce are not adequate for decision making.

Oil and grease (a generic contaminant category including petroleum, synthetic, and biological "oily" materials) are measured throughout the water column as a part of several wastewater outfall monitoring programs. However, because most oil and grease float, and therefore are rarely found above detection limits in the water column, it is not cost effective to sample there. In addition, dissolved and dispersed oil and grease derive from many other sources, such as oil seeps, bilge pumping, aerial fallout, refinery effluents, stormwater runoff, and even from natural biological sources. Therefore, they are equivocal indicators, at best, of outfall impacts. It was suggested that floating grease balls, which can more directly be related to wastewater outfalls, would be a better indicator.

Biological and chemical oxygen demand (BOD and COD, respectively) have traditionally been measured as part of benthic monitoring programs around wastewater outfalls. These parameters were originally included in receiving-water monitoring programs because they were used by sanitary engineers to monitor in-plant sewage treatment processes. There was a consensus among practitioners in the bight that these parameters are less biologically relevant in an open ocean environment and therefore cannot be meaningfully interpreted. It was suggested that measuring organic carbon and carbon flux, ammonia-nitrogen, and total nitrogen would be more ecologically meaningful (see pages 28–29).

As a condition of their 301(h) permit, the County Sanitation Districts of Orange County are required to routinely measure a wide range of chemical contaminants, even though many of them are never found in effluent or sediments. This represents a large expenditure of resources where past experience has shown there is likely to be little contamination. In contrast, in Los Angeles City's Hyperion monitoring program, the search for chemical contamination is more focused. Priority pollutants in the effluent are measured monthly (quarterly for volatile organics), thus providing regular information about what is entering the environment. During the first monitoring year, all priority pollutants are measured in sediments, trawl-caught fish and invertebrates, and sport fish. Contaminants that were not found in the first year are not monitored during the second and third years. In the fourth year, the entire range of priority pollutants is measured again.

The city of San Diego is required to monitor suspended solids in the water column around the Point Loma wastewater outfall. However, because sampling stations are near the Point Loma kelp bed, the suspended solids samples sometimes contain larval crustaceans or pieces of kelp, seriously compromising the utility of this outfall plume indicator. More useful approaches here might be to measure light transmission or use sediment traps to determine fluxes of suspended particles in the water column.

The location of sampling stations can also be inappropriate. The sampling grid around the Point Loma outfall contains a southern control station that is of little or no use as a control because it is close to a dredged material disposal site and the sediments are predominantly extremely coarse sand. Even assuming that movement of material from the disposal site has not compromised the control station, the unusual sediments will necessarily be associated with a different benthic community, making meaningful comparisons with the outfall stations difficult if not impossible. At the northern end of the sampling grid, the city's permit required sampling a control station called B-2, located in 50 ft of water. This station was sampled for years, but was never used in analyses because there were no other stations at this depth. A transect had originally been planned at 50 ft, but all the stations, with the exception of B-2, were located in areas of rocky bottom, where benthic grab sampling was impossible. The city requested that it be allowed to stop sampling B-2 and instead add a control station at 150 ft. This would have been a more efficient use of resources because the sampling grid already included a transect at the 150-ft outfall depth, but lacked a control. Implementing this change in the sampling design required several years and a public hearing, at a cost of wasted sampling effort at B-2 and reduced ability to monitor impacts at 150 ft.

As part of its NPDES permit to discharge cooling water from coastal power plants, the Southern California Edison Company is required to monitor for thermal effects on marine resources despite the fact that nearly 20 years of studies have documented the limited nature of these effects. This example is indicative of the lack of clearly defined endpoints in monitoring studies, which hinder reallocation of monitoring resources to unresolved or more pressing issues.

Histopathology, tissue analysis for contaminants, and enterococcus measurements have been included as routine parts of monitoring programs, even though many participants in the case study believe they require more research and development before they can provide useful information. The panel stresses that these comments derived from a sincere desire to produce useful information and a frustration with requirements to perform studies whose results are ambiguous or uninterpretable.

Several unresolved issues apply to tissue chemistry studies. The basis of presentation of data has not been standardized, making it difficult to interpret and compare results. For example, data may be presented on a dry weight or lipid weight basis, with each method presenting a different picture of contaminant levels. The problem of confounding due to seasonal and reproductive cycles also has not been resolved. In the spring and summer, fishes' reproductive season, fats are mobilized and transferred from the liver to the gonads. This may affect contaminant levels not only in these tissues but in others as well (Cross et al., 1986). There may be differences in both the timing of reproductive cycles and in tissue chemistry between different species. However, because it is not possible to predict which species will be

Permit-by-Permit Approach

The existing regulatory framework necessarily forces monitoring into a permit-by-permit approach to environmental problems in the bight. This results in monitoring programs that look at each activity in isolation from all others. Taking monitoring results at face value requires making two related and scientifically dangerous assumptions. The first is that there are no cumulative, overlapping, or interactive effects. The second is that the measurements taken to document the effects of a particular activity reflect that activity and no others. Neither of these assumptions is especially robust, as several examples will make clear.

The County Sanitation Districts of Orange County carry out a monitoring program around their wastewater outfall. Within or very near the sampling grid are other biological and physical/chemical patterns that interact with the effects of the outfall. On the eastern edge of the sampling grid is an active EPA interim-designated, dredged material disposal site for dredged material from upper Newport Bay. This dumpsite is in temporary use, and many of the contaminants found in the outfall effluent are also found in the dredged material. Just inshore of the outfall is the mouth of the Santa Ana River, which seems to be associated with a plume of modified sediments that affect benthic community patterns in the sampling grid. On the western edge of the sampling grid is a region of elevated contaminant levels of unknown origin. The permit-by-permit approach makes it more likely that these potentially confounding influences will be disregarded when designing a monitoring program for the Orange County outfall.

The city of Los Angeles and the County Sanitation Districts of Los Angeles and Orange counties all carry out fish trawling programs around the Hyperion, White Point, and Orange County wastewater outfalls, respectively. These sampling programs are used to independently assess the effects of each outfall on fish populations in the region of the outfall. However, it is likely that at least some portion of the studied fish populations moves throughout the entire area. This means that, for example, the monitoring program at White Point may actually also be measuring some effects of Hyperion and Orange County.

The city of Los Angeles' trawl sampling program in Santa Monica Bay is designed to document effects of the Hyperion outfall on fish populations. However, the Southern California Edison Company and Los Angeles Department of Water and Power also operate coastal power plants in Santa Monica Bay. Entrainment of large numbers of fish larvae by cooling water intakes and impingement of adults may affect fish population sizes and community structure in the bay. In addition, some of the species monitored in the trawling program may spend part or all of the juvenile phase of their abundant enough for tissue chemistry studies at any one time, dischargers are allowed to sample species of opportunity. This means that no two dischargers consistently sample the same suite of species at the same time. It also means that the same discharger will sample different species in successive surveys. Given the unresolved issues related to seasonal cycles and interspecies differences, the lack of consistent target populations makes it extremely difficult to interpret tissue chemistry data and relate them to discharges.

The issues of standardization of measurement techniques, seasonal physiological changes, and inconsistent target species also plague histopathology studies. In addition, the interpretation of histological changes in marine organisms can be demanding and ambiguous, and it was suggested by several participants that this technique is not yet suitable for routine monitoring.

In contrast to these two examples of incompletely developed techniques being used as routine monitoring tools, the city of Los Angeles' Hyperion monitoring program includes a microlayer study that is explicitly experimental in design. The permit states that the first-year sampling results will be used to determine the scope and direction of future monitoring. It also defines first-year requirements of an otter trawl sampling program and stipulates that first-year data be used to refine the sampling design for subsequent years. In addition, Hyperion's permit includes specific language that allows for further flexibility as needed (see pages 63 and 65). These examples suggest that permits can be structured to be flexible and adaptable. This produces two important benefits. First, it allows for improving and refining monitoring programs as data become available. Second, it allows resources to be used more effectively by recognizing that some questions are more appropriately dealt with in a research context than in routine monitoring. Repeatedly collecting the same data over and over again is not always the best way to address unresolved questions about the utility of new technical methods.

The Southern California Edison Co. recognized this when it began its program of special studies in the marine environment (see Chapter 4). The special studies were explicitly experimental in nature because it was understood that it is often difficult to define research programs succinctly enough to make them part of routine monitoring. They produced information that was important in understanding and reducing impacts without becoming a part of routine monitoring activities. On the other hand, Edison personnel pointed out to the case study panel that they found the data from mandated monitoring programs based on conventional measurements to be of relatively little value in managing marine resources.

life cycle in harbors and marinas in and around the bay. This example illustrates that patterns in fish populations (particularly population size and community structure) measured by the Hyperion monitoring program may actually reflect the effects of a suite of impacts, some of them occurring on other life stages than those targeted by the monitoring program. Other sources of effects were not incorporated into the design of the Hyperion trawling program despite the outfall's close proximity to coastal power plants; permitted and accidental discharges from oil refineries, stormwater drains, and nonpoint sources of pollution; marinas; and contaminated juvenile habitats.

The permit-by-permit approach to establishing monitoring programs also leads to important inconsistencies among monitoring programs. Some of these reflect the fact that permits were written at different times, with more recent permits incorporating more up-to-date knowledge. However, other inconsistencies reflect differences in approach or expertise among the regional water quality control boards and EPA Region IX personnel. As discussed more completely below, such inconsistencies make it difficult to develop an integrated view of impacts and trends in the bight as a whole.

Specific examples of inconsistencies among monitoring programs include the following:

- The city of Los Angeles has a flexible approach to measuring priority pollutants in sediments and organisms, whereas the County Sanitation Districts of Orange County measure priority pollutants regularly.
- Trawl sampling around wastewater outfalls is usually conducted quarterly or semiannually, but trawl sampling around coastal power plants is conducted every two months.
- The city of Los Angeles conducts offshore water quality sampling weekly because its discharge is near areas of intense water-contact recreational areas, whereas the County Sanitation Districts of Orange County conduct offshore water sampling monthly for some parameters and quarterly for others.
- No two dischargers consistently use the same organisms for tissue chemistry measurements.
- The city of San Diego is not required to conduct trawl, rig fishing, or tissue chemistry studies, although other dischargers are required to do so. However, trawls are performed on a voluntary basis to contribute to a regionwide assessment of fisheries resources.

TECHNICAL DESIGN AND IMPLEMENTATION

This section summarizes the extent to which monitoring programs in the Southern California Bight meet the criteria for technical design presented in Figures 5-1 to 5-4. The discussion is organized around

- the issues of statistical design of monitoring plans,
- the establishment of field and laboratory procedures that ensure valid, high quality measurements, and
- data management strategies.

Statistical Design

There is still room for improvement in how statistical tools—quantitative null hypotheses, statistical models, quantification and partitioning of variability, optimization analyses, and power tests, for example—are applied to program design. These tools are beginning to be applied to monitoring programs in the bight, and the EPA has produced 301(h) guidance documents that provide instructions for their use; however, lack of clear quantitative objectives prevents effective application. New monitoring tools can be properly applied only in the context of clear statements of management needs and the questions and/or hypotheses that reflect them. The following examples illustrate this point:

- Power tests can estimate the likelihood that a sampling plan will detect a change, such as an increase in the diversity of the benthic infaunal community of 0.1, 0.2, 0.3, 0.4, etc. Without guidance from regulations or ecological theory about what specific amount of change is important, it is still possible to perform power tests for a wide range of possible changes, then choose the sampling plan that is most likely to detect change (any change). However, a more useful approach would be to decide that a specific increase of 0.3, for example, is a strong indicator of outfall enrichment effects, then use power tests to design a sampling plan with a high probability of detecting that precise amount of change.
- Measurements of background variability can be extremely useful in designing efficient sampling plans. In spite of this, great time and expense could be wasted attempting to measure variability on all scales (e.g., feet to hundreds of miles and days to decades). However, if managers determine that only present effects within 6 mi of an outfall are of interest, other variability scales can be deemphasized. If managers are also interested in change from year to year, annual background variability would become relevant. If managers are interested in longer-term trends—more than 10 years, for example—then interannual variability on that time scale would become relevant.
- There has been discussion in the development of 301(h) monitoring plans about the proper number of "replicate" benthic grabs to take at each station. This discussion has used the results of technical design tools such as power analysis. Even these tools cannot resolve the issue because there is no one right number of replicates to collect. The proper number depends on the question(s) being asked, the amount of predicted change sampling

should detect, and the sources of variability that could obscure monitoring results.

This last point deserves further discussion because of the mistaken assumption that the same number of replicates is appropriate for all situations. As one example, if concern is focused on the difference in diversity inside and outside the ZID boundary at one point in time, then a different number of grabs at each station may be required than if the concern is about how the relationship between diversity inside and outside the boundary changes over five years. Further, if concern is focused on how diversity inside the ZID changes over five years in response to changes in the output of suspended solids, then another number of grabs might be appropriate.

Some of the deficiency in the consistent and proper use of technical design tools in monitoring programs in the Southern California Bight stems from the incorrect use of statistical concepts. Two such important concepts are "significance" and "replication."

Portions of permits and regulations state that a particular activity shall not cause a "significant" alteration, change, decrease, or degradation in some physical, chemical, or biological parameter. The California ocean plan (State Water Resources Control Board, 1987) defines a "significant" difference as "a statistically significant difference in the means of two distributions of sampling results at the 95 percent confidence level." The problem with this definition is that it provides no guidance in determining how large a change is of importance and should therefore be detected by a monitoring program. This is because virtually any change can be a statistically significant difference, depending on the intensity of sampling. Thus, a monitoring program with a low intensity of sampling will find only large changes to be statistically significant, while one with a high intensity of sampling could find even minuscule changes to be statistically significant. Permits and regulations should replace the word "significant" with another such as "meaningful" or "important" and then define the terms clearly.

There is an emphasis on replication in Southern California Bight monitoring programs but no equivalent awareness that replication has at least two different meanings, and that many aspects of a sampling plan can conceivably be replicated. Replication is loosely used to refer to the process of collecting repeated measurements, samples, or comparisons. However, in a stricter sense, it refers to the process of repeating entire experimental treatments. In addition, a sampling plan may have many levels of sampling, any and all of which may be repeated. For example, a monitoring program set up to determine whether benthic infaunal diversity inside the ZID is decreasing over time with respect to diversity outside the ZID might include:

- several stations inside the ZID,

- several stations outside the ZID,
- one or more "replicate" grabs at each station, and
- several sampling periods over time.

This sampling plan thus includes replicate grabs at each station, replicate stations within each area, and replicate times or surveys during which all stations are sampled. Depending on the resolution desired, technical design tools such as power and optimization analysis might indicate different numbers of "replicates" at each level of sampling (e.g., two grabs per station, five stations per area, and nine surveys over time). When different kinds of "replication" are not clearly distinguished, monitoring programs tend to emphasize repeated samples at a single place and time. A balance has to be struck between extensive replication of all samples and spreading limited sampling resources over other levels of a sampling plan.

Field and Laboratory Procedures

Many field and laboratory procedures are of commendable quality in Southern California monitoring, where an attempt is made to use state-of-the-art methods, particularly in the larger programs. In addition, an emphasis on improving monitoring methods has resulted in standardization of invertebrate taxonomy, benthic grab sampling techniques, and chemical analysis procedures. Monitoring programs at the municipal wastewater discharges benefit directly from research carried out at SCCWRP. New questions and new methods of sampling and analysis have been incorporated quickly into ongoing monitoring programs.

Although monitoring methods are state of the art, they may not always be adequate to address monitoring objectives. Such an example was described above with reference to tissue chemistry and histopathology studies. As another example, public health surveillance methods are not precise enough to detect brief episodes of mild illness among swimmers due to bacterial or viral agents in marine waters. In addition to the epidemiological problems, studies of putative viral agents are hampered by lack of culture techniques. There is growing recognition that there may well be a better indicator of fecal contamination than the coliforms (i.e., the enterococcus group), and health agencies are actively acquiring information to assess these new indicators. Because epidemiological studies are expensive to perform and marine epidemiological studies often yield equivocal results, especially when performed on a small-scale local basis, state and federal public health and water quality agencies have been reluctant to fund such studies.

Data Management

Data management is vitally important to monitoring efforts because it determines the final accessibility and utility of the data. Data management should include quality control procedures that ensure data accuracy at every step from initial collection to final analysis and reporting. It should also include methods for making the data readily available in usable formats to those responsible for analyzing and examining them. Another important but little-recognized aspect of data management is the importance of specifying data tabulation methods, structures, and handling procedures before a sampling program starts. This allows data to be collected and processed in ways that are appropriate to their final use, dissemination, and storage. This specification of data management procedures at the beginning of a program can save significant effort and money that would otherwise be spent correcting errors in raw data, analyses, and reports.

At present, there is a wide variety of approaches to marine monitoring data management in the bight. In spite of this variety, the panel found that the major monitoring programs all have well-developed and active systems for ensuring the accuracy and quality of their raw data. These data are continually reviewed and updated when necessary. The following examples are representative of data management approaches in the bight.

The 301(h) programs configure their data in the National Oceanographic Data Center (NODC) format and are now required to submit monitoring data to the EPA Ocean Data Evaluation System (ODES). ODES, designed to provide ready access to 301(h) data, has recently become fully operational and includes formal quality control procedures. However, not all historical outfall monitoring data are in digital format. For example, the Los Angeles County sanitation districts have computerized past monitoring data from the White Point outfall, whereas such data from the County Sanitation Districts of Orange County are available only in written reports.

Data from the California Cooperative Oceanic Fisheries Investigation (CalCOFI) program are in NODC format and are available in published data reports. The Southern California Edison Company maintains its own data base for a wide range of monitoring data. The National Marine Fisheries Service and the California Department of Fish and Game have fisheries monitoring data available on magnetic tape; however, these agencies do not maintain user-oriented data bases to provide access to these data. Scientists at the Scripps Institution of Oceanography monitor temperature and wave energy and provide these data on magnetic tape on request. Data from smaller studies (e.g., Los Angeles Harbor, Marina del Rey) are typically stored on floppy disks or on consultants' computer systems.

The city of San Diego and the County Sanitation Districts of Orange

County have initiated analogous programs to centralize and automate their in-house data management procedures. These systems provide computerized data entry functions that automatically perform quality control checks on a range of raw data. Validated data are stored in a centralized data base and a set of menu-driven options allow users to update and extract data. Additional menu options permit users to automatically produce standardized regulatory reports and automatically format data for submission to ODES. Finally, the systems incorporate links to a variety of analytical tools, such as spreadsheets and analysis and graphics software.

The taxonomic efforts of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT) and the ODES data base represent important steps in setting consistent standards for standardization, quality control procedures, error checking, and digital formats for monitoring data. However, there is currently no easily accessible, user-oriented data base system to provide access to analysts interested in integrating data from several different kinds of studies. Such a system would greatly facilitate attempts to study regional and longer-term questions related to environmental effects in the bight.

There are two prototypes for such a system, each with its own strengths. These are the operational environmental data base developed by the Environmental Research Group of Southern California Edison and ODES. Both systems are unusual in that they include extensive quality control procedures and on-line documentation and are designed to permit data analysts to use menu-driven routines to readily extract data needed for analyses. Southern California Edison's system was designed to perform the following functions:

- store corrected and updated archival versions of important data sets so that all analysts access the same version of the data;
- store important data sets in a data base management system that provides the ability for easy extraction, updating, and manipulation of data;
- provide comprehensive on-line documentation of methods, error corrections, data characteristics and peculiarities, and publications for each data set;
- provide automated browse, search, retrieval, and reporting facilities;
- provide flexible links to the Statistical Analysis System (SAS) and other data analysis systems; and
- allow easy addition of novel data types to the system.

This system is fully operational and contains a wide variety of monitoring studies in standardized formats, thus facilitating comprehensive analyses. These studies currently include:

- benthic infauna and sediment data from monitoring programs at San Diego, Los Angeles city and county municipal wastewater outfalls;
- Southern California Coastal Water Research Project's (SCCWRP's) 198-ft (60-m) survey;
- Scripps' shoreline temperature data for the west coast of the United States, and wave energy and wave direction database;
- California Department of Fish and Game sportfish catch;
- National Marine Fisheries Service commercial fish catch data;
- benthic infaunal and sediment data from the Bureau of Land Management (BLM) study of the bight;
- complete impingement data for all Southern California Edison coastal power plants;
- data from bightwide ichthyoplankton studies and fish trawl studies performed for Southern California Edison; and
- selected Marine Review Committee studies.

This system is proprietary and is not accessible to scientists outside of Southern California Edison. It does, however, illustrate that such comprehensive databases can be constructed. The main strength of Southern California Edison's system is that it contains a wide range of data from biological and physical oceanographic studies that are bightwide in scope. The experience of constructing this database substantiated the fact that locating, acquiring, correcting, and standardizing disparate data sets is a significant effort.

The other system that points the way toward bightwide data management is ODES. ODES is intended as a national database to contain 301(h) monitoring data, which includes (among others) benthic infauna and sediment chemistry, otter trawl, water quality, and other data types. It includes a wide range of menus that assist users in extracting and combining data from different studies, in performing common types of analyses, and in creating maps and graphics. In addition, ODES provides for extracting raw data for analysis with other software packages.

Despite its strengths, ODES has shortcomings that restrict its utility and that must be corrected in any future system that successfully provides access to a range of monitoring studies. There is widespread dissatisfaction with ODES within the Southern California monitoring community. This dissatisfaction results from the difficult and labor intensive procedures required to format data for submission to ODES. It also stems from the lengthy wait required for feedback to requests for new species codes and answers to technical questions. There is therefore a long delay between the initiation of the submission process and the final availability of the data. Users of ODES have access only to the analysis and reporting routines that have been programmed into the system. While many of these are very useful, they do not cover the full variety of approaches required for a comprehensive analysis of monitoring data. Requests for additional analytical tools must wait until they can be programmed into the system, since ODES does not allow users to directly access other analysis systems. Users can, however, extract data from ODES and download them to their own computer systems. Another shortcoming is that when new data types are encountered, ODES must be reprogrammed to accept them, a process that can take several months. In contrast, data base systems that are designed for adaptability use table-driven data definition approaches to allow for rapid modification of data base structures.

ODES provides the ability to combine data from more than one study in order to perform regional or national analyses. However, in practice this capability is severely limited because ODES lacks an aggressive program to update data sets in the system and to standardize taxonomy among data sets. Experience in the bight has shown that such taxonomic updating and standardization is crucial if data sets are to retain their utility and if different studies are to be combined. Species names, particularly of benthic invertebrates, change continually over time as scientists adjust taxonomic affinities. Thus, for data sets to remain current, even historical data must be updated regularly. Taxonomic standards invariably differ among different studies. This is true even when efforts are made to use common standards. Thus, in order for data from two or more studies to be combined, careful attention must be paid to reconciling these superficial dissimilarities. As a result of the lack of such updating and standardization procedures, only analyses that do not depend on merging or matching species data can be performed with ODES. Such analyses include those using derived variables such as diversity indices, total abundance, numbers of species, or summaries of higher taxonomic groups.

TECHNICAL INTERPRETATION AND DECISION MAKING

The ultimate goal of monitoring is to provide data and information to support informed decision making. In this section, the technical interpretation of data obtained in monitoring programs and its use in decision making are addressed. Some examples show that monitoring data have been adequately interpreted and used in decision making. Overall, however, considering the effort that has been put into data collection, no comparable effort and expense has been devoted to translating that data into useful information and using it in decision making.

In spite of the shortcomings in the interpretation and decision-making process (reviewed below), it is important to recognize that monitoring information has played a significant role in many far-reaching management decisions in the Southern California Bight. Water quality and bacteriological monitoring data from Santa Monica Bay documented the severity and extent of nearshore contamination from sewage discharges in the 1940s and 1950s. These data helped make the case for construction of offshore outfalls in 1957 and 1959 that dramatically reduced nearshore sewage contamination.

In 1977, the California Department of Fish and Game closed the abalone fishery from Palos Verdes Point to Dana Point. This decision was based on monitoring surveys and catch data. As another example, scientists of NOAA's Ocean Assessments Division have used data from SCCWRP and the municipalities to evaluate environmental conditions relating to the body burdens of chlorinated hydrocarbons in coastal marine organisms (Mearns and O'Connor, 1984; Matta et al., 1986; and Mearns and Van Ness, 1987).

The inability of the city of San Diego's Point Loma wastewater treatment plant to consistently meet bacterial standards contained in the 1983 California ocean plan (State Water Resources Control Board, 1983) for offshore kelp beds contributed to a decision by the city to extend its outfall farther offshore. Earlier monitoring data generated by Southern California Edison Company showed that unacceptably large numbers of fish were being taken into cooling-water intakes of power plants. As a result, intakes were redesigned with velocity caps and other changes to reduce entrainment and impingement. Monitoring data were then used to confirm that the design changes were effective.

Data generated over the last eight years by the Marine Review Committee on the environmental impacts of SONGS will be used to make decisions about changes in the design or operation of the cooling-water system. These data will also be used to support the development of mitigation measures to offset impacts documented through monitoring. The recently released first-year report for the 301(h) monitoring program performed by the County Sanitation Districts of Orange County resulted in adjustments to the districts' permit. In addition, the data in the report suggested that no changes were needed in the waste discharge or treatment processes.

By far the greatest effort in data interpretation between the 1950s and the present has been the work of SCCWRP scientists. Starting with the 1973 report on conditions in the bight and implications for management (SCCWRP, 1973), their periodic reports and scientific journal publications have become internationally recognized. Although their work has included much more than evaluation of routine monitoring data, it has resulted in improved monitoring methods and in quality control activities that increase the reliability of the data. In fact, the scientific publications of the majority of SCCWRP scientists are cautious, if not silent, on interpretation of monitoring data with respect to regulatory actions. Instead, their interpretations generally focus on environmental conditions and, to a somewhat lesser extent, on possible impacts of pollutants.

On a smaller scale, the Channel Islands National Park monitoring program has generated data since 1981 from diving surveys at 14 stations, conducted primarily by volunteers. These data are used to make decisions about visitor access, harvesting of resources, and development of the park resource. As another example, the program conducted by Occidental College for Southern California Edison was originally related to monitoring the effects of waste heat discharge from coastal power plants. It has also yielded useful resource information on a sedentary reef fish community. This latter example demonstrates that if data were made available scientists would find monitoring programs useful for filling in information gaps about marine resources.

In many instances, the use of monitoring data is not as clearcut as in the examples just cited. In some cases, it is difficult to document whether decisions were based on monitoring results, particularly when decisions were made not to change existing procedures.

In some instances, disagreements about the interpretation of data can hamper the ability to make resource management decisions. For example, during the 1940s and 1950s, major differences of opinion among scientists working on sardines hindered implementation of the management measures needed to protect this fishery resource (Baxter, 1982). Scientists from the U.S. Bureau of Commercial Fisheries contended that year-class size was independent of the size of the spawning stock and that catch size therefore had no effect on stock size in subsequent years. California Department of Fish and Game scientists believed that there was a strong link between year-class size and spawning stock size. By the time the disagreement was resolved in 1966 in favor of the Department of Fish and Game, the fishery had collapsed.

Complicating such scientific uncertainty is the fact that the societal implications of resource decisions can be quite extensive. Thus, decisions based on limited data impose risks that managers have to weigh against expected benefits and the time constraints of required actions. For example, decisions involving the economic livelihood of fishermen who harvest pelagic fish stocks may require a decade to correct if the result of the decision is not as expected. In fact, a decade or more may sometimes be required to produce a signal sufficient to determine if the decision was correct.

In addition to scientific uncertainty, institutional limitations can limit the effective use of monitoring information in decision making. All too frequently, data reports sent to regulatory agencies are not subjected to thorough scrutiny and summarized for policy makers and the public. This is because the human resources and budgets of the regulatory agencies are inadequate to interpret the growing masses of data generated each year and translate them into information useful to environmental managers and policy makers.

Dischargers and other permittees often perform extensive analysis and interpretation of monitoring data. However, their reports are usually too lengthy and detailed to be readily accessible to policy makers and the public. In most cases, budgets earmarked for data analysis and interpretation by both the regulatory agencies and the permittees are judged inadequate. It was the consensus of the case study participants that monitoring data were incompletely synthesized and inadequately used in decision making. This is unfortunate because many monitoring reports contain extensive data sets that are not available in scientific journals even though they are peer reviewed to rigorous standards. In spite of this, some are suspect because the quality and quantity of the reviews are not documented. A statement at the beginning of such reports documenting the review process would have a favorable payoff in building confidence among the aware lay public who are trying to sort out technical issues. There are some exceptions to this generalization (for example, Matta et al., 1986) that provide both data, frequently from monitoring programs, and analysis of data. These are widely distributed and are cited in many regulatory documents such as the 301(h) decision documents.

Another institutional limitation derives from the differing responsibilities of the various regulatory agencies involved in managing monitoring activities. The EPA acts primarily as an enforcement and compliance agency. The state of California, through the State Water Resources Control Board has primary responsibility for the development of ocean policy in general, represented by the California ocean plan (State Water Resources Control Board, 1987). Evaluation of monitoring data is one part of the process of developing this policy and the specific regulatory actions intended to implement it. The state board establishes overall policy and the regional water quality control boards determine individual permit requirements.

Both the EPA and the regional boards believe that most monitoring programs are well planned, well executed, and yield data that are useful in demonstrating compliance and in documenting regulatory changes. The state board, however, has the additional responsibility of identifying beneficial uses of marine resources and establishing water quality objectives to protect those uses. The state board staff believe that the question, "Are beneficial uses being protected?" is of more fundamental importance than mere compliance, but that monitoring data are not presently adequate to answer this question. As explained in the next section, this may be because the available monitoring data are not sufficient to fully address this broader question and because the specific questions are not asked precisely enough to guide monitoring efforts.

OVERALL ORGANIZATION OF MONITORING

The preceding description and analysis of monitoring efforts in the Southern California Bight show that monitoring has achieved important successes. It has documented the extent of impacts from point sources such as power plants and wastewater outfalls. It has tracked the improvement of gross contamination in areas such as Los Angeles Harbor and the beaches of Santa Monica Bay. Longer-term studies, such as those carried out at the White Point outfall by the County Sanitation Districts of Los Angeles, have provided valuable insights into how human impacts interact with natural disturbances.

However, the same analysis shows that the existing monitoring system does not address all important sources of impacts (e.g., storm drains). In addition, Figure 5-5 shows that many important resources are affected by more than one kind of human or natural perturbation. In spite of this, there are no monitoring programs that focus on resources by integrating data about the cumulative effects of more than one kind of perturbation. This is because the monitoring system derives predominantly from a focus on regulating specific human activities, rather than managing natural resources. Finally, Figure 5-6 shows that many contaminants and other sources of change act on time and space scales much larger than those of the typical monitoring program. As a result, the existing monitoring system has difficulty resolving bightwide patterns of change that may be just as important as the localized impacts that are the current focus of monitoring.

In Chapter 5, four questions were identified as being especially pertinent to evaluating the overall success of monitoring in the bight. These were as follows:

- Does monitoring address clearly stated management and societal objectives?
- Does monitoring address the major environmental problems facing the bight?
- Do the spatial and temporal scales of monitoring reflect those of the major environmental problems?
- Are monitoring resources allocated effectively both within and among monitoring programs?

The foregoing analysis provides the basis for answering these questions. In each case, the summary answers below are focused on assessing the performance of the monitoring system as a whole, rather than on individual monitoring programs.

Objectives

As described previously, there are different kinds of objectives that motivate monitoring, from the broad concerns of the public to the detailed specifications of individual monitoring programs. These objectives can be classified as those pertaining to the effects of specific activities (e.g., dredging), to the overall status of important resources (e.g., kelp beds), and of the bight as a whole. Because of the institutional structure of the regulatory and permitting system, only the first of these is addressed in any detail by the existing monitoring system. In Figure 5-5, this can be represented as looking only at each row in isolation, ignoring both columns and the matrix as a whole.

While objectives relating to measuring and managing the impacts of individual activities may not always be clearly stated, they nevertheless are the unmistakable focus of permits and monitoring programs. In contrast, important concerns about the status of resources and the bight as a whole are not manifested in the more detailed objectives that structure monitoring programs.

Major Environmental Problems

There can be no arguing with the fact that monitoring addresses many of the major environmental problems facing the bight. However, it is also clear that the existing monitoring system cannot address other problems that are just as pressing. These include nonpermitted sources, such as storm drains and atmospheric input of contaminants. They also include cumulative impacts stemming from the action of more than one kind of human or natural perturbation on a single resource. Finally, the existing monitoring system cannot adequately assess the existence and importance of large-scale and long-term environmental trends in the bight.

The importance of these other environmental problems is a result of two major trends in the bight. First, increasing population and attendant utilization of marine resources have magnified the potential for cumulative and large-scale impacts. Sources of contamination and perturbation are more numerous and more closely spaced than in the past. Second, the existing monitoring and management system has been remarkably successful in removing gross pollution from the bight. As a result, concerns about cumulative impacts and subtle changes over time have become relatively more important.

Spatial and Temporal Scales

As a general rule of thumb, the spatial and temporal boundaries of a monitoring program should match those of the phenomena it is attempting to monitor. As Figure 5-6 shows, the spatial and temporal boundaries of existing monitoring programs match those of some but by no means all of the relevant processes in the bight. As a result, the existing monitoring system has only a limited ability to resolve trends and changes occurring on larger time and space scales. Such trends and changes can be natural, in which case they represent a moving background against which human impacts must be compared. Large-scale changes can also result from human impacts that by their nature cannot be restricted to one location (e.g., DDT contamination).

The CalCOFI program (e.g., Chelton et al., 1982) and the Bureau of Land Management study of benthic communities in the bight (e.g., Thompson and Jones, 1987) provide examples of the ability of larger-scale sampling programs to describe important patterns that cannot be detected by point-source monitoring programs. Because monitoring occurs throughout the bight, the existing monitoring system has the potential for measuring events on larger time and space scales. However, this potential cannot at present be fully realized because separate monitoring programs are not sufficiently coordinated and integrated.

Allocation of Monitoring Resources

Despite the large amount of time and money (at least $17 million per year) spent on monitoring in the bight, it is not possible to perform all the monitoring that would be desirable given unlimited resources. The available resources should therefore be allocated based on criteria that prioritize environmental problems and impacts. Such a process should be based in part on an overall assessment like that summarized in Figure 5-5. At present, this is not possible. Each monitoring program is developed independently, and its scope and cost are established in negotiations between the permittee and the regulatory agencies. As a result, some problems receive a disproportionate share of monitoring resources while others receive little or none.

SUMMARY

The analysis of monitoring in the Southern California Bight led to conclusions and insights about individual programs and about the monitoring system as a whole. In general, monitoring programs in the bight use state-of-the-art methods and produce accurate and reliable data. In addition, monitoring data have contributed to many important decisions related to pollution abatement and the management of natural resources. In general, monitoring has been successful in identifying and quantifying the impacts of such point-source activities as wastewater outfalls and coastal power plants.

In spite of these successes, the panel found several shortcomings, some related to the execution of individual programs and some to the institutional structure of the monitoring system as a whole. The most important of these were:

- poorly stated objectives that provided insufficient guidance for monitoring efforts;
- inability to monitor the effects of activities falling outside the existing permit structure;
- inflexibility that inhibits needed adaptability;
- overemphasis on a permit-by-permit approach to monitoring and environmental decision making, thus limiting the ability to monitor cumulative and large-scale impacts;
- insufficient use of statistical design tools in the development of sampling and measurement plans; and
- lack of a bightwide data management system to support integration and synthesis of data from different studies.

The panel performed a preliminary synoptic assessment of environmental problems in the bight. This assessment, combined with the analysis of individual programs, led to important conclusions about the structure of the overall monitoring system. Because the existing system focuses on individual permitted activities, it is unable to foster the higher level planning and coordination needed to assess cumulative and larger scale environmental problems. In addition, the focus on individual human activities makes it difficult to focus on important resources that are affected by more than one type of impact. As a result, it is difficult to draw conclusions about the status of the bight as a whole and about whether beneficial uses of the marine environment are being protected.

7
Conclusions and Recommendations

CONCLUSIONS

Current Monitoring Effort

1. The total amount of money and effort expended by public utilities, private industry, and government agencies in monitoring of water quality, natural resources, and public health in the Southern California Bight is extraordinarily large. A conservative estimate is that current annual expenses for monitoring far exceed $17 million (see Chapter 4).

2. Most water quality monitoring programs are organized around the outfalls of several large coastal municipal wastewater treatment plants and electric power generating stations and are elaborately detailed in their requirements.

3. The California Cooperative Oceanic Fisheries Investigation (CalCOFI) for natural marine resources in the California Current system and Southern California Bight has been unparalleled among marine resource monitoring programs in terms of its commitment to a long-term time-series assessment. However, station coverage has been reduced by budget cuts.

4. Significant sources of chemical and microbial contaminants contained in riverine and stormwater discharges to the bight have not been adequately monitored as part of the marine monitoring system in the bight.

Lack of Program Integration

5. There are no formal institutional mechanisms for integrating the findings from the different ongoing monitoring programs. This means that there is no mechanism for integrating the results from monitoring of various point sources with each other or with the findings of the resource or public health monitoring programs.

6. There is no system for interrelating the findings of various monitoring programs to present a coherent picture of the whole. This precludes evaluating the human impacts of bightwide human inputs in the context of natural variability, and thus it is difficult to evaluate whether corrective actions are effective.

7. There currently is no effective system for reporting findings of monitoring programs to the public, the scientific community, or policy makers.

8. The monitoring programs in specific permits have been designed to address small-scale discrete questions with little attention paid to the overall question of the status of natural resources and water quality of the Southern California Bight as a whole.

9. In the past, there have been recommendations for bightwide water quality, public health, and natural resource monitoring programs. These recommendations have not been implemented.

RECOMMENDATIONS

A Regional Approach

10. The questions of bightwide inputs and their impacts are growing in importance. Many of them could be addressed in a regional monitoring program. A regional program should be established that:

- addresses specific questions about the current environmental condition of the bight and the resources therein, including those associated with public health impacts, spatial and temporal trends in natural resources, nonpoint source and riverine contributions, nearshore habitat changes, and cumulative or areawide impacts of large and small point and nonpoint source inputs;
- incorporates standardized sampling, analysis, and data management methods;
- establishes a comprehensive data base management system for all monitoring and resource data in the bight, which could provide access to the historic and current data needed to perform comprehensive and bightwide analyses;

- can be facilitated through the coordination of local, state, and federal entities, which integrate their regulatory, data, and management needs and responsibilities to optimize the utilization of available resources;
- can be achieved largely through coordination, integration, and modification of existing efforts, rather than through the addition of another layer of monitoring in the bight;
- can be developed to involve the public and the scientific community as participants in the program;
- includes built-in mechanisms to ensure that its conclusions are effectively communicated to the public, the scientific community, and regulatory agencies; and
- includes mechanisms to require periodic review and to allow easy alteration or redirection of monitoring efforts when they are justified, based on the results of the monitoring or new information from other sources.

The effort to develop a regional program will need to address the needs of the agencies and parties involved in monitoring; synthesis of existing data and information in order to construct meaningful questions and null hypotheses; drafting of an organizational framework; drafting of a monitoring program; and allocating the financial resources required to carry out the program. If properly implemented, the benefits and the costs of a regional monitoring program can be shared by all sectors of society. However, it should also be noted that a regional approach ultimately has to consider the effects of competing uses on land, water, and air quality, and tradeoffs between short- and long-term costs and benefits.

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